COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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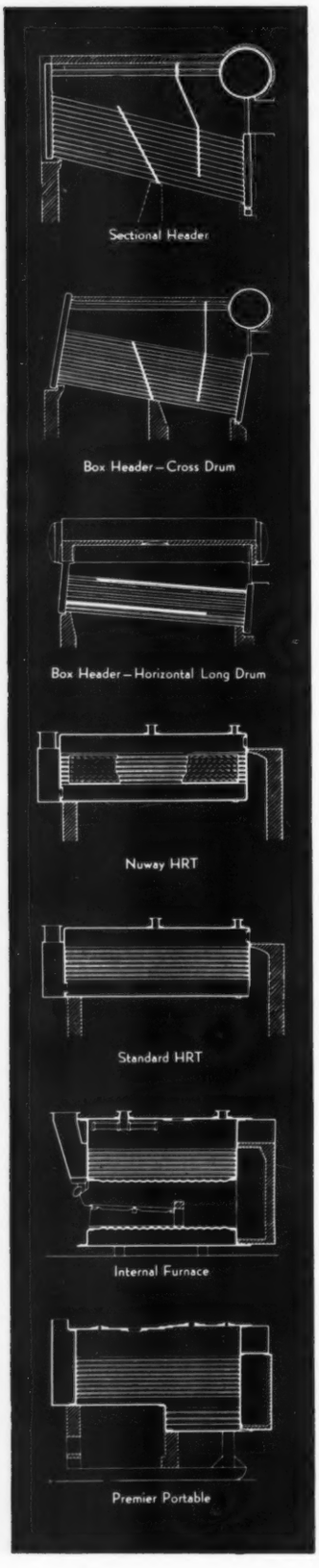
Lubricating Oil for Circulating Systems of Steam Turbines

Burning Blast-Furnace Gas at Delray



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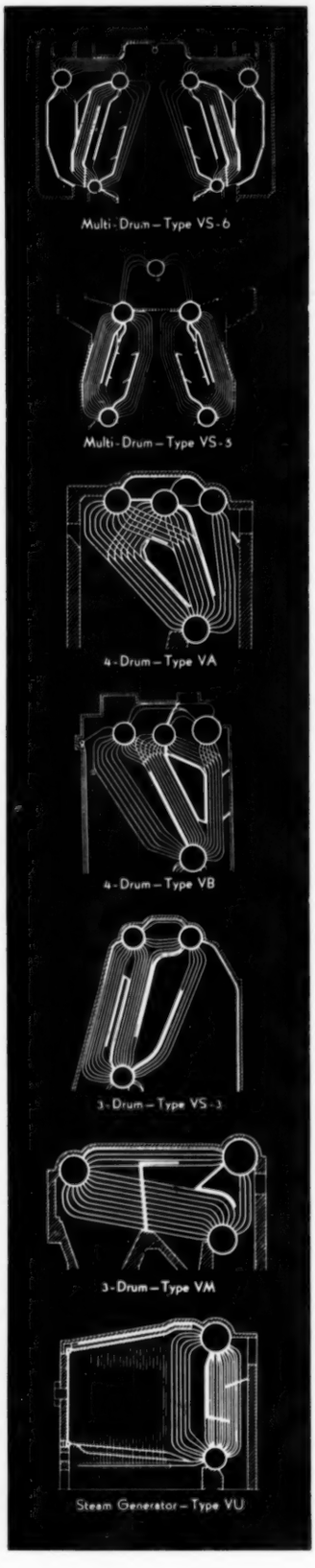

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VOLUME NINE NUMBER SIX

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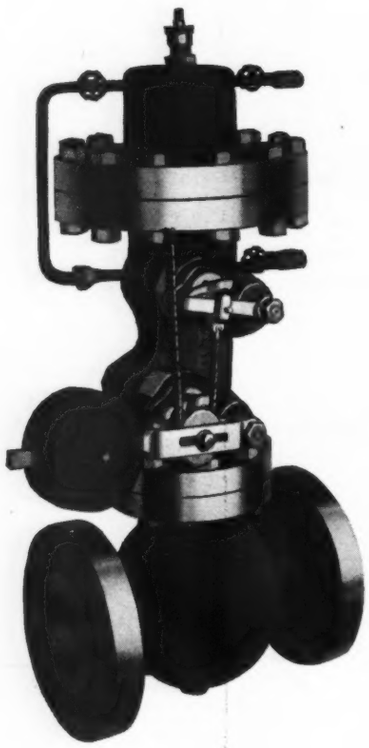

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EDITORIAL

An Affront to the Engineering Profession

IN forwarding to Congress the recent report of the New York State Power Authority, the President appears unfortunately to have given weight to a vicious attack on the integrity of certain prominent members of the engineering profession.

This report, which was an obvious attempt to justify publicly-owned water power developments on the grounds that hydro power is cheaper than steam power, attacked the findings of the National Resources Committee, a body appointed by the President, with Secretary Ickes as Chairman. This Committee very properly sought the aid of specialists in various fields and the chapter on power in its report was prepared jointly by M. M. Samuels, Electrical Engineer of the Federal Power Commission, and A. A. Potter, Dean of Engineering at Purdue University and Past President of the American Society of Mechanical Engineers, with the acknowledged assistance of such well-known engineers as C. F. Hirshfeld, George A. Orrok, Frank F. Fowle and others.

This chapter, based largely on statistical information and available data, appears to review in an impartial manner the case of steam versus water power. For instance, it states in part:

> "In the stationary steam power plant the fixed charges have been going up during recent years while operating expenses have been going down, yet better engineering has greatly reduced the actual cost per unit of power output. . . . Hydroelectric and steam electric plants are complementary sources of power. . . . Present low costs of steam power necessitate discrimination in developing water power sites. . . . Hydroelectric plants are practical where good water sites are available, not too far from load centers, with well-sustained continuous water flow, or with water storage that can be developed at low cost. Water power can supply power in certain localities during peak load periods at low cost per kilowatt-hour. In many localities, however, absence of fuel cost does not make up for high fixed charges and low reliability of water power. The high efficiency and low fixed charges now possible in large fuel-burning plants place hydroelectric developments at a disadvantage in most sections of the United States if low cost of power is the objective. Water power plants, due to their high fixed cost, depend even more than do fuel-burning plants on a high use factor or load factor."

Most engineers, conversant with the facts, will agree with these observations, but the fact that the Committee of Utility Executives had quoted from this report aroused the ire of Frank P. Walsh, Chairman of the New York State Power Authority, who, in an effort to impute bias to Dean Potter's views, stressed the fact that the latter is a member of the Prime Movers Committee of the Edison Electric Institute. Mr. Walsh, who, incidentally, is a lawyer, may or may not know that this is a strictly technical committee which is held in the highest regard by the engineering profession. That Dean Potter, together with two other well-known professors, is privileged to sit in at its meetings, is not only a recognition of his standing in the field, but also affords him an opportunity to obtain first-hand knowledge of power plant performance and practice.

While it is true that many hydro projects in the past have been privately developed, they represent, with few exceptions, the more favorable sites as to initial cost, stream flow and proximity to load centers. At that, the development costs have, in general, been high compared with steam plants, a fact that may be verified by consulting the records on file with the Federal Power Commission.

Omitting the question of rates to the consumer, which tends to befog the issue, a rational approach to the problem of government-owned water power versus steam-generated power would be possible, provided a reasonable allocation of fixed charges were made between power production, flood control, navigation, etc. Until an acceptable basis for such charges is established no fair comparison can be made.

Mr. Walsh, whose avowed objective is accomplishment of New York State's plan for the public development of the St. Lawrence River power resources, gives hypothetical figures to prove that such hydro power would be cheaper to the consumer than privately generated power from steam stations.

No one can take issue with that part of the President's memorandum of transmittal to Congress which states that "It is in the public interest that, if there be two sides to any question, both sides should be fairly and freely laid before the public," but an attack on the integrity and views of outstanding members of the engineering profession, such as contained in the report, can hardly be construed as a *fair* presentation of the case.

It is unfortunate that the Administration has not seen fit to take the engineering profession into its confidence in handling its power problems. Practically all the commissions charged with these duties are made up of men with legal rather than engineering background. Perhaps this is because the engineer is trained to reason from facts to conclusions, whereas the lawyer by both training and practice is accustomed to reason from the objective to such evidence as will make out his case.

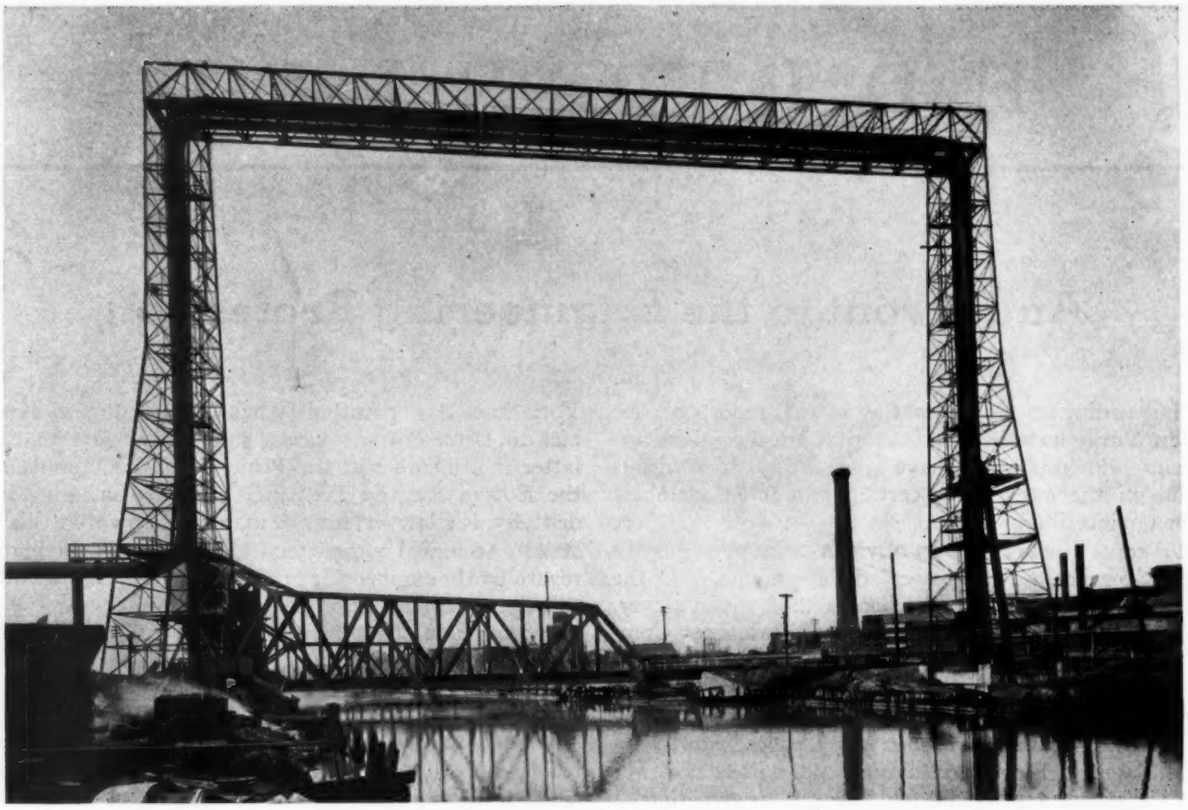

Fig. 1—Gas line carried by bridge 150 ft above the River Rouge

BURNING BLAST-FURNACE GAS AT DELRAY

By A. W. THORSON
The Detroit Edison Company

For the past six months blast-furnace gas has been burned as auxiliary fuel over the underfeed stokers of three boilers at the Delray Power House of The Detroit Edison Company. While there has been no appreciable effect on efficiency the use of gas effects an annual saving of 60,000 tons of coal, representing about 20 per cent of the total fuel requirements. The installation is described in detail.

EARLY in 1936 The Detroit Edison Company entered into a long-term contract with The Great Lakes Steel Corporation for surplus gas from its Hanna Furnace Division operations at Zug Island, this gas to be burned as auxiliary fuel over the stokers at the Delray Station. On March 29, 1937, construction was completed and gas was delivered to Delray.

A typical analysis of this blast-furnace gas resulting from use of Mesabi ore is as follows:

	Percentage by Volume
Carbon monoxide	24.0
Carbon dioxide	11.0
Hydrogen	3.0
Oxygen	0.3
Methane	0.2
Nitrogen	61.5
Total	100.0

Lower heating value, 93 Btu per cu ft at 30 in. Hg and 60 F

The quantity of gas available averages 35,000 cfm, which is the equivalent of 7 tons of coal per hour. At this rate of flow, the annual coal consumption will be reduced by approximately 60,000 tons, which is at present about 20 per cent of the total fuel requirements for the power house.

Three of the five boilers now installed are equipped for gas firing. Coal on underfeed stokers and gas are burned simultaneously. Specially designed inter-tube burners, the combustion control scheme and purging with boiler flue gas are particularly interesting features of this installation.

A preliminary survey showed that the gas must be transmitted across the River Rouge and through the property of the Solvay Process Co. to the Delray Power

House. Carefully made cost estimates indicated it to be more economical to cross the river overhead than by tunnel or trench. Accordingly, a steel bridge, shown in Fig. 1, was built carrying the pipe line 150 ft above water level to provide necessary clearance for boat traffic. Having crossed the river, the line runs underground to the power house property, thence overhead into the boiler room. The pipe throughout its entire length is 48 in. diameter, the underground portion having a thickness of $^1/_2$ in., and the overhead $^3/_8$ in. The underground portion was welded into 80-ft sections, protected from corrosion by tar paper and bitumastic paint and joined with Dresser couplings. The remainder of the pipe line was welded except for necessary flanged joints. Drip pockets to collect water which can be pumped out from the surface of the ground, were provided under the line at 1000-ft intervals.

The designed capacity of the transmission line is 50,000 cfm at 30 in. Hg and 60 F. Since the gas pressure at the blast furnaces is not sufficient to overcome the pressure loss through the line and accessory equipment, it is boosted by a centrifugal compressor. This booster is located so that it operates on cleaned gas, thus minimizing outages for cleaning and maintenance.

Gas Cleaning Equipment

Raw blast-furnace gas contains dust which may at times amount to 10 grains per cu ft. This dust is abrasive; it may fuse in the furnace and stick to boiler tubes, or deposit in pipe lines necessitating frequent cleaning.

Some boiler plants firing gas alone require a reduction in the dust loading to 1 grain per cu ft; others firing gas and pulverized coal, simultaneously, limit the maximum to 0.05 grain per cu ft. This is necessary because the gas dust and coal ash may unite to form a eutectic mixture with a low-fusion point, resulting in serious tube slagging. Gas engine plants may require a reduction in the dust loading to 0.01 grain per cu ft because of abrasion of engine cylinders. Since the long gas line in the present case is in itself an efficient dust collector, the degree of cleaning required at the furnaces was governed by the necessity of keeping the line clean. Accordingly, the existing primary dust catcher and tower washer were supplemented by a cyclone separator and a Cottrell precipitator. This equipment is designed to reduce the dust loading to 0.05 grain per cu ft.

Meters and Calorimeters

Gas quantity through the line is measured by a segmental-orifice flow meter, supplemented by pressure and temperature recording elements. This type was selected because of the possibility of dust accumulation ahead of a concentric orifice plate, thus destroying the accuracy of the meter. The segment, together with its pressure taps, is located at the top of a horizontal section of the gas main, thus avoiding dust accumulation.

The flow meter was calibrated in position by temporarily installing further downstream a carefully made concentric orifice plate. Tests were made by blowing air through the line at different rates of flow, making proper corrections for pressure, temperature, viscosity and humidity conditions at both orifice plates.

The higher heating value of the gas is measured continuously by a Thomas calorimeter. The accuracy of this instrument is verified by periodic comparison with results from a Junkers flow-type calorimeter. Fig. 2 shows the arrangement of apparatus in the calorimeter room. The gas sample is drawn from the line after the cleaning equipment. It is bubbled through a 10 per cent solution of NaOH in water, and then through a cotton drier before it enters the calorimeter. When making comparative tests, the gasometer is filled from the sample line, and the two instruments are supplied from the same sample.

Gas Burners

The gas is piped into the plant by means of a 48-in. header, extending the length of the boiler room, from which it flows through a 36-in. branch connection, U-tube water seal and burners into each boiler furnace as shown in Fig. 3. In the design of this equipment, resistance to flow was minimized to prevent unnecessary transmission losses.

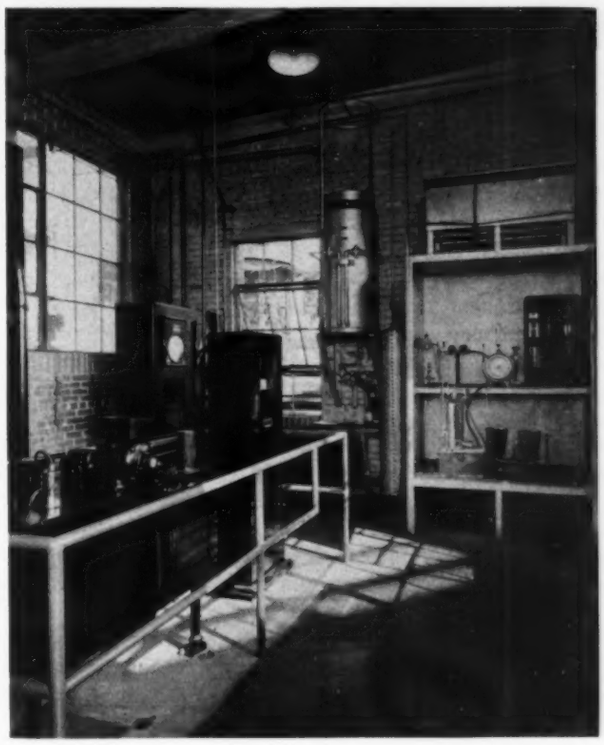

Fig. 2—Apparatus in the calorimeter room

Four diffusion-type burners are installed in the rear wall of each gas-burning boiler, firing in a horizontal direction across the top of the coal fuel bed as shown. The use of burners of standard design would have required rebuilding the rear furnace walls in order to provide openings larger than were available between the furnace wall tubes. To avoid this major reconstruction, an inter-tube burner was designed and built, and with some modification of its first form, has been satisfactory. Those built first could not withstand the high-temperature radiant heat of the furnace when no gas was being burned. The addition of a refractory section behind the wall tubes and directly in front of the burner ports corrected this difficulty. Fig. 4 shows a sketch of the improved burner. The inserts in the burner ports are cut from lintel tile and set in place, and the remainder of the refractory poured in plastic form No maintenance on

this type of burner has been necessary to date, nor has any slag accumulation over the burner ports been experienced.

These burners were designed for a normal maximum of 7500 cfm of gas and 10,500 cfm of air, with a range of operation of 4 to 1. Air supply is tapped off the main preheated air duct leading to the stoker. As shown in Fig. 4 alternate envelopes of air and gas mix at the sheet metal nozzles, the shape of which was determined by a scale model test.

Gas supply to each burner is controlled by a grid valve shown in Fig. 5. Valve *g* is fully opened or closed by power cylinder *h* and controller *k* from the valve *m* on the boiler gage board, or automatically as will be described later.

Since gas is always burned over a coal fire, no pilot burners or other provisions for its ignition were made, such as would be required if it were burned alone.

Combustion Control

Because the combustion characteristics of coal and blast-furnace gas differ widely, proper control of combined firing is particularly important. The original design, burning coal only on stokers, is for manual operation, excess air being regulated by recording CO_2 and CO plus H_2 instruments. Control of combined firing was therefore adapted to the use of this same equipment. Since the theoretical CO_2 for the gas is nearly 24 per cent by volume as compared to 18.5 per cent for the coal, it is apparent that the proportions of the two fuels must be known before CO_2 can be used as a guide in firing. This problem was solved by metering the gas to each boiler.

Further than this, however, the gas quantity available and its pressure depend on conditions of operation at the source of supply, whereas the air pressure available to burn the gas depends on the boiler steaming rate. It was decided, therefore, that in addition to metering gas, some form of automatic proportioning of gas and its combustion air was essential.

The scheme adopted for firing control is as follows: The available gas, together with its combustion air, is supplied through the burners, with automatic regulation of the desired air-gas ratio. The balance of the required load is carried by coal which, with its combustion air, is manually regulated. Having determined by test the optimum air-gas and air-coal ratios, the desired percentages of CO_2 in the mixed flue gas are known for different boiler steaming rates and different gas-coal ratios. The fireman then observes the boiler steaming rate and gas volume, and selects the desired value of CO_2 from data furnished him. Using this as a guide, he then makes final adjustment to obtain maximum CO_2 without CO and H_2.

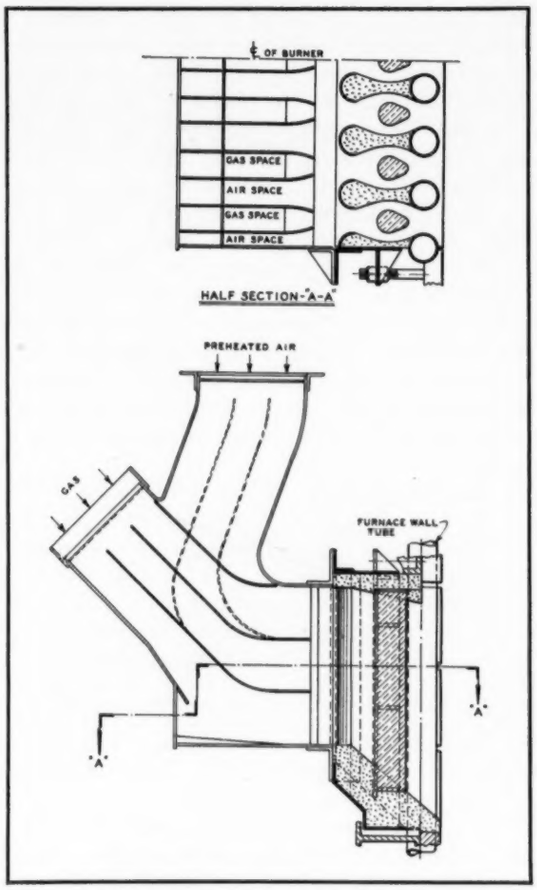

Fig. 4—Sketch of improved burner

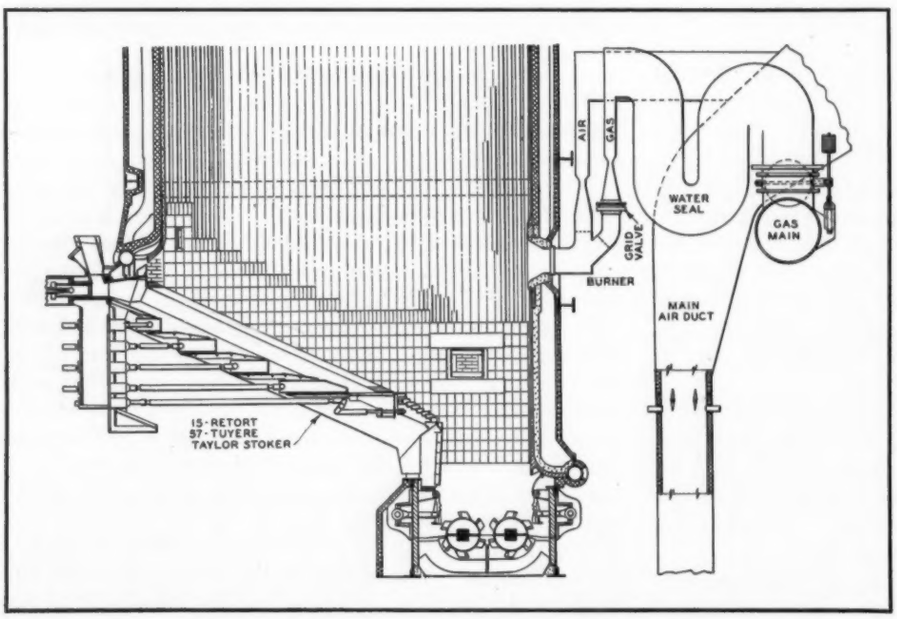

Fig. 3—Showing how gas is introduced into furnace

The equipment for air-gas ratio control is shown in Fig. 5. Metering is effected by venturi boxes *a-a* in the gas and air ducts approaching the burner. The differential pressure across the venturi metering gas to each burner is used to actuate a diaphragm controller *b*. This in turn varies the loading pressure under the diaphragm of a second controller *c*, the hydraulic valve of which moves power cylinder *d* and louver dampers *e*. The resultant change in air flow changes the differential pressure

across the air venturi which affects the diaphragm of controller *c* and restores equilibrium. The gas quantity through each burner is indicated on the boiler gage board by a flow gage connected across the venturi. The boiler gage board is also equipped with an electrical indicator for each burner, *f*, to show the percentage opening of the air louver damper.

If the normal gas flow suddenly increases, as indicated by the flow gages, the air dampers open to supply more air. When they reach the full open position, as shown by the electric indicators, any further increase in gas flow will produce an over-rich fuel mixture. When this condition occurs, either more burners may be cut in, thus making less air required per burner or, if all burners are in use, more air pressure must be provided. This may be done by closing a damper in the main air duct beyond the burner air off-take, and raising the speed of the forced-draft fan to supply the necessary air volume to the stoker through the partly closed damper. One, or both, of these adjustments must be made until the indicators show that the air dampers are again within range.

As a result of this scheme of control, gas firing has added but one task to the duties of the fireman, namely, that of maintaining the air duct dampers within range. In practice, normal gas-flow variations can be controlled by changing the number of burners in service. It is rarely necessary to throttle the main air duct.

Regulation of the air-gas ratio to each burner is obtained by a leak-off valve and orifice placed between the loading diaphragm of the two controllers, as shown in Fig. 5. By adjusting the leak-off valve the pressure drop across the orifice is varied, creating a variable difference in loading pressures between the two controllers, thus causing controller *c* to reach equilibrium for different positions of the air damper. This adjustment permits the setting of any desired air-gas ratio from zero to 1.5 times theoretical.

Purging

Blast-furnace gas, like other gaseous fuels, will unite with air to form an explosive mixture. Hence all space through which gas flows must be purged of air before admitting gas. This is done with inert flue gas taken from the boiler breechings, cooled to about 100 F and scrubbed in an air washer, and delivered by a blower of sufficient size to purge the entire system in about one hour. The entire transmission line is purged when for any reason the gas pressure has dropped to atmospheric. In addition, whenever one of the boiler shut-off valves has been closed, the gas space between it and the furnace is purged before it is again opened.

One pipe joint in each connection of the purging system to the gas system is broken and blanked after purging is completed. This precaution is necessary to prevent possible leakage of gas into the hot breechings.

Gas Valves

All valves in the gas system, except the grid valves at the burners, are of the rubber-lined butterfly type. An emergency shut-off valve is located just outside the boiler-room wall, which can be closed electrically by a manually-operated switch in the boiler room.

A valve is located in the branch to each boiler, held open by a solenoid energized from the induced-draft fan motor circuit. Stoppage of the fan, or operation of a push button on the gage board, closes the valve. All butterfly-type valves are opened by power cylinders. Air is supplied to them in the same manner as an auto tire is filled, thus preventing the possibility of air pressure holding a valve open when it must be quickly closed.

A grid valve at each burner is controlled from the boiler gage board, as previously mentioned. These valves also close automatically with low gas main pressure, to avoid total loss of pressure and the necessity of subsequent purging. Referring to Fig. 5, a drop in gas pressure to one inch water gage causes controller *n* to operate valve *o* and supply 8-lb air under the diaphragm of controller

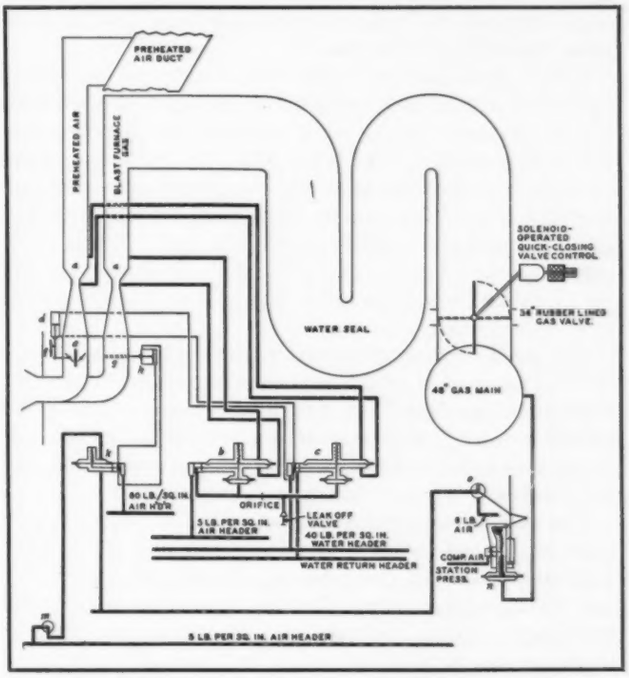

Fig. 5—Arrangement for controlling gas supply

k, overbalancing the effect of 5-lb air above the diaphragm, thus closing grid valve *g*. Restored pressure automatically opens those valves which were open. Operation of this automatic closing feature, however, requires adjustment of stoker fuel bed rating. Therefore, an alarm sounds when gas pressure drops to two inches water gage, warning the firemen of a possible loss of gas.

Safety Precautions

Blast-furnace gas is highly toxic because of its carbon monoxide content. Since it is also colorless and odorless, a leak might not be noticed until a person in its vicinity was overcome. For this reason, a warning agent such as is commonly added to odorless natural gas is used periodically to indicate the presence of possible leaks. If serious trouble should develop, gas masks located at convenient places throughout the plant furnish protection for the operators.

The branch connections to boilers each contain a U-tube water seal, shown in Fig. 3, which is filled with water when maintenance men are working inside the boiler. This insures against possible valve leakage.

In addition to the safety precautions already described, an explosion head is provided on the end of the 48-in. header, which is extended through the boiler-room wall

out-of-doors for this purpose. A fiber diaphragm, 3/8 in. thick, is used which will rupture at about 6 lb per sq in. and discharge gas out-of-doors to relieve high pressure.

Effect on Plant Economy

Preliminary estimates of the effect of gas firing on plant economy indicated that the boiler-room efficiency would not be affected materially. This was confirmed when, after the gas-burning installation went into service, plant operating results showed no appreciable difference chargeable to gas burning. When operation was begun, the gas burner controls were set for theoretical air-gas ratio. It was believed that sufficient excess air normally came through the ashpit and up the rear wall to complete combustion of the gas.

Later, heat-balance tests were made to determine optimum combustion conditions. Results showed that the theoretical air-gas ratio through the burners produced best results. With less than this ratio, a portion of the air required to burn the gas had to come through the fuel bed. Consequent incomplete mixing resulted in unburned combustible in the flue gas. When theoretical air was supplied to the burners, the coal fire could be operated normally, with no unburned combustible loss in the flue gas.

The tests further substantiated the fact that no appreciable loss or gain in efficiency is chargeable to the gas. Heat balances show that combined firing produces lower ashpit loss and increased steam temperature, but this advantage is at least partly offset by increased stack loss and higher total auxiliary power requirements.

The steam temperature was increased about 20 deg F, because the non-radiant gas flame reduced the radiant heat absorption in the furnace, thereby sending hotter gas to the superheater. It was impossible to take full advantage of this, however, because a baffle change was necessary to prevent exceeding the safe temperature of the superheater tubes.

The stack loss when burning gas is greater: first, because the total theoretical flue-gas volume from the gas alone is about 65 per cent greater than that from the coal; and second, because the stack gas temperature is slightly higher as a result of the increased gas temperatures throughout the boiler unit.

As a result of greater stack gas volume, the induced-draft fan is more heavily loaded. This is offset slightly by a reduced load on the forced-draft fan, because the theoretical combustion air requirement for the gas is about 20 per cent less than that for the coal. The total auxiliary power consumption per boiler has been increased about 15 per cent by addition of gas firing.

The gas-burning installation has now been in service for six months, and to date no serious operating troubles have developed. No changes in design have become necessary, with the exception of those to the burner which have been described. The reduction of fuel bed ratings on the gas-fired boilers has facilitated boiler-room operation. Since less coal is now being burned, stoker maintenance is reduced, and improved cleanliness of heat-transfer equipment has decreased soot-blowing and steam-lancing.

The use of blast-furnace gas at Delray is an interesting example of cooperation between an industrial and a utility resulting in improved fuel utilization and benefit to both.

Prime Movers Report on Pulverizers

The Prime Movers Committee of the Edison Electric Institute has just issued its annual report on "Combustion" in which the subcommittee summarizes the information from operating companies and manufacturers concerning pulverized fuel as follows:

"In almost all pulverized fuel installations, an essential requirement of the firing system is quick response to changes in load over a wide range of output. The bin system with its reservoir of prepared fuel has in the past been considered particularly suitable for these conditions, but this advantage is being offset by providing feeders of liberal capacity at mills and by recent developments in direct-fired equipment.

"A continuing major difficulty with direct firing is the effect of moisture in the fuel on operation of the raw coal feeder. Recourse has been had to direct gravity bypass around feeders of the disk type, for emergency use, to provision of excess capacity on dry-coal basis, and to close coordination of raw-coal feed with primary air input.

"The amount and temperature of primary air to the mill affect capacity when grinding wet coal. Where the mill output is controlled by primary air flow, the coal will not be carried out of the mill until the surface moisture has been evaporated. It is therefore necessary to have an adequate supply of preheated air. Tests indicate that under extreme moisture conditions, coal leaves the mill with a moisture content equal to the inherent moisture of the coal.

"Maintenance cost for mills, as given by operating companies, varies between wide limits. Several report mill maintenance as high as 6.5 to 7 cents per ton with mills installed prior to 1930, while other companies report costs as low as about 1.3 cents per ton. In one case, maintenance costs of 2 to 2.5 cents per ton are recorded when pulverizing No. 4 buckwheat anthracite with a grindability of 45 to 55 per cent. Manufacturers have concentrated on improvements in design and materials used in pulverizer equipment, with the result that maintenance costs have been materially lowered within the last few years.

"In some types of mill the fineness is not affected by changes in output, while in others there is a marked decrease in fineness as output increases. One company, using revolving drum mills, finds that with an increase in boiler output from 70 to 125 per cent of normal rating the percentage of coal through a 200-mesh screen decreases from 5 to 20 per cent, with a slight increase in the coarser particles. The fineness of the pulverized coal also changes with mill wear.

"Corrosion of exhauster fan blades, liners and of collectors and piping, reported by one company, is attributed to condensation after shutdown. Protective coatings applied to the exhauster wheels have arrested corrosion for a short time; these, however, fail by erosion in too short a time to warrant repeated recoating. Exhausters which have been sand-blasted and lead-sprayed fail from this type of wear within a year. Stainless steel blades of 12–14 chrome are now in service on one fan, and while no results are as yet reported, favorable results are anticipated and similar construction therefore has been specified for equipment now on order."

Segregation of Coal in an Industrial Steam Plant Bunker

By R. A. SHERMAN, Fuel Engineer,
and
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That variations from hour to hour, or day to day, in the size of coal delivered to a stoker should adversely affect the satisfactory performance of the stoker is to be expected. Users of coal have called upon producers to load coal in cars uniformly as to size and to maintain uniformity from day to day. Although the desirability of such uniformity is not denied, experimental data in this report, obtained as a part of the program of research on industrial uses of coal by Bituminous Coal Research, Inc., show the extent of segregation that may occur in the power-plant bunker and urge that attention be given to the problem by designers and operators of power plants. The conclusions drawn from these tests are most important.

THE hourly change in coal size and particle size distribution at the hopper of a stoker is known to affect the operation of stokers of all kinds by disturbing all other efforts to produce and maintain a uniform fuel bed. The effects are recognized somewhat as follows:

1. The coarser, unignited coal offers less resistance to the flow of air than the smaller coal or uniform mixtures.
2. Because the smaller coal often has a higher ash content and a lower ash-fusion temperature than the coarser coal, the tendency to clinker formation will be greater when small coal is being supplied.
3. Coarser coal does not tend to cake together as strongly as the smaller fuel, except in cases of coals which become very plastic while coking, and hence, will produce a weaker coke which will permit freer passage of air for combustion.
4. The coarser coal will burn out more readily because it receives more air due to its lower resistance, and because it has a lower bulk density and, therefore, a lower feeding rate on conventional stokers on which coal is fed by volume displacement.
5. The capacity to burn coal when maximum steam output is needed may be limited by the foregoing items, especially when the coal contains large amounts of small sizes, as wet, fine coal may ignite slowly.
6. Because of the difference in the moisture contents of the fine and coarse coal the heating value of the coal will vary with the screening analysis.

NOTE—
After this article had been written one of the authors was requested to present the material at the Appalachian Coals, Inc., Fuel Engineering Conference held at Kalamazoo, Michigan, on November 3, 1937. This was done. EDITOR

The conclusion does not necessarily follow that the variation of size with time of all coals used on industrial stokers will adversely affect the operation at normal or low ratings. Coals which become very plastic on heating may cake almost as completely in any of the size distributions that one is likely to encounter. Furthermore, if the ash contents of the coal sizes do not vary appreciably and the ash-fusion temperatures of all sizes are high, no change in clinkering may be expected.

The most serious effect of coal size variation will probably be noted with a medium caking coal having an appreciably higher ash content and a lower ash-fusion temperature in the small sizes, particularly when the smaller coal is burned at high stoker ratings.

Variation in the coal received at the stoker hopper from an overhead bunker is caused principally by segregation of the coal in the bunker. This will occur with the common 2-in. nut-slack stoker coal by injudicious handling upon filling the bunker, whether or not the coal is well mixed as received at the plant. A very defined segregation of particle sizes is produced when coal of appreciably wide size distribution is unloaded from a conveyor belt or chute and allowed to fall to a conical pile. The coarser particles tend to roll and slide to the bottom and outer edge of the pile and, conversely, the smaller particles tend to remain directly below the line of fall.[1,2] When there is a difference in specific gravity of the particles, as caused by changes in ash content, a "density segregation" is known to occur in which the denser particles, regardless of size, tend to remain with the particles directly beneath the line of fall.[3]

Segregation Test of Coal

As a part of the survey of the use of bituminous coal on industrial underfeed stokers, being conducted by Battelle Memorial Institute for Bituminous Coal Research, Inc., a test was conducted at a plant where bituminous coal was burned on underfeed stokers. The purpose of the test was to obtain data that would illustrate segregation of sizes of coal in a typical installation and to determine, if possible, the effect of the coal segregation upon the performance of the stoker fuel bed with a coal of this type.

[1] See "Coal Segregation Problems" by David R. Mitchell, *Proceedings*, 15th Fuel Engineers Meeting, Appalachian Coals, Inc., July 10, 1936.
[2] See "Coal Segregation and Its Reduction" by Henry F. Hebley, *Ibid.*
[3] C. W. H. Holmes, *Colliery Engineer*, Vol. 11, p. 40, 1934.

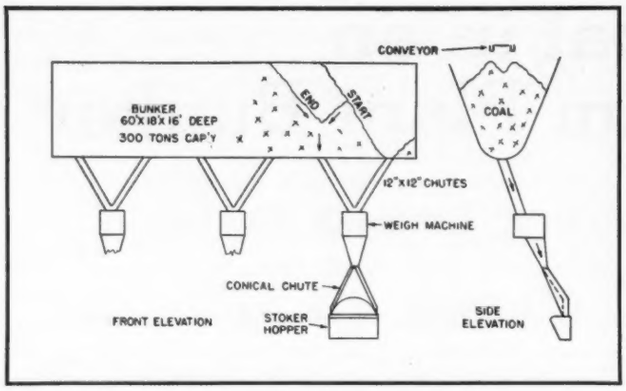


Fig. 1—Design of bunker and coal chutes

The 2-in. nut-slack size coal was received from the mine by rail in hopper-bottomed cars. The coal was dropped into a track hopper from which it passed through a roll crusher to a bucket elevator. The crusher was so adjusted that it effected little reduction in the size of the coal, and the buckets discharged to the horizontal conveyor belt above the center of the coal bunker. The belt was unloaded by a conventional distributor which was locked in certain positions along the bunker, depending upon which part of the bunker was to be filled. Half of the coal was discharged on each side of the belt to a double-pointed conical pile with the usual segregation.

Fig. 1 shows the arrangement of the bunker and hopper. Two tubes were installed to supply coal by gravity from the bunker to each stoker but, as a matter of practice, only one tube fed coal at a time until the coal supply in the bunker over that tube was exhausted. At the time of this test there was coal over only one of these tubes, as shown in the sketch.

The weigh machine discharged 200-lb increments to the coal chute below. The machine was started at intervals of 20 to 30 min and stopped after the lower chute was filled. The conical type of chute was designed to deliver the coal without segregation along the length of stoker hopper under the condition that the chute be kept filled.

The five-ram underfeed stoker was of 1929 design. Its speed was controlled manually to maintain the fuel bed contour and uniformity of burning desired by the operator. The total projected stoker area was 100 sq ft; of this, 31 sq ft represented dump plates. The average coal burning rate, based on the 69 sq ft of effective area of the stoker, was only 29.1 lb per sq ft per hr. The 5150-sq ft boiler was operated at 20,000 lb of steam per hour during the test without appreciable fluctuation.

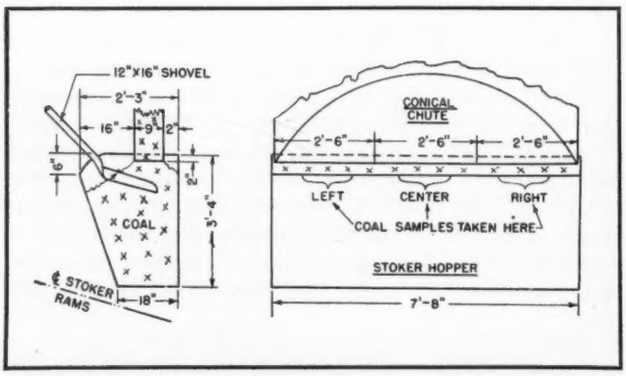


Fig. 2—Method of taking increments from the underfeed stoker hopper

Fig. 2 shows how coal samples were taken from three positions in the stoker hopper. An increment of approximately one cubic foot of coal was taken from each zone during every 20 min of the 11-hr test. Each increment of coal was made up of five successive scoopfuls from directly under the conical chute. A total of 99 increments of coal, each with an average weight of 53.7 lb was taken. This represented a total of 27,400 lb drawn from the bunker.

Observation of the fire was through the side doors at the front and rear of the furnace during each hour and also at intervals after a change in coal size was noted. Neither the operator nor the sampler could notice a change in the nature of the burning which was independent of the handling of the stoker by the operator. No appreciable clinkering occurred at the relatively low burning rate used. The ash softening temperature was 2600 F and the coal was of the coking type.

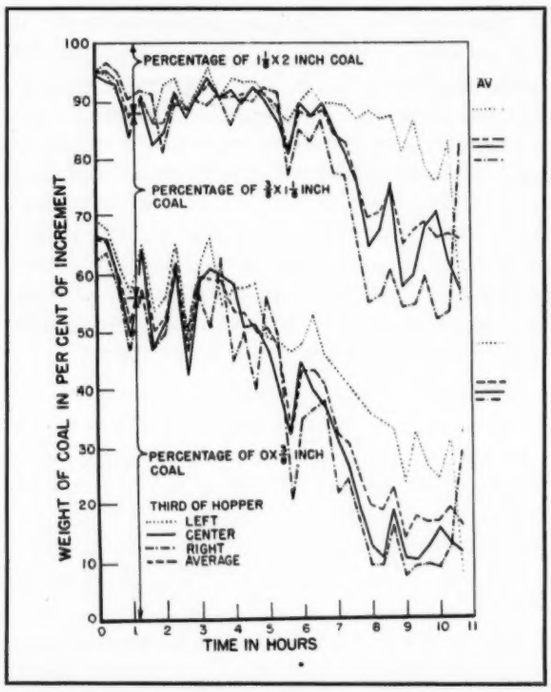


Fig. 3—Variation of screen analysis of coal at stoker hopper

Fig. 3 shows the results of the size analysis in which each of the 99 increments was screened over round-hole screens into three fractions, $1^1/_8 \times 2$ in., $^3/_8 \times 1^1/_8$ in. and $0 \times {}^3/_8$ in. Data are plotted cumulatively, the percentage of $^3/_8 \times 1^1/_8$-in. coal being shown by the difference between the upper and the lower curves, and that of the $1^1/_8 \times 2$-in. coal by the difference between 100 and the upper curve. The coarseness of the coal increased markedly during the test. How the bunker was filled is not known, but one may assume from the data that the coal had been laid down almost directly over the tap hole, the center of the cone having been drawn down first.

The coal on the left third of the hopper was distinctly smaller in particle size than that at the center despite the use of a conical, non-segregating type of chute. Proper functioning of the distributor chute demands that the

chute be filled at all times and that no lateral segregation exist in the filling tube. These conditions were not maintained at this plant, the chute being filled periodically by manual control of the weighing machine motor. This effect, however, is rendered negligible in the present considerations by using averaged figures.

Variation in Ash Content

Each of the 297 increments produced during the screening operation was crushed and sampled for determination of the ash content. Fig. 4 shows the average ash contents of the left side, center and right side samples taken at 20-min intervals. These curves show that the ash content was greater, the greater the size of pieces. They also show that the ash content of the 0 × 3/8-in. coal was quite uniform throughout the time of sampling, departing little from the average content. The ash content of

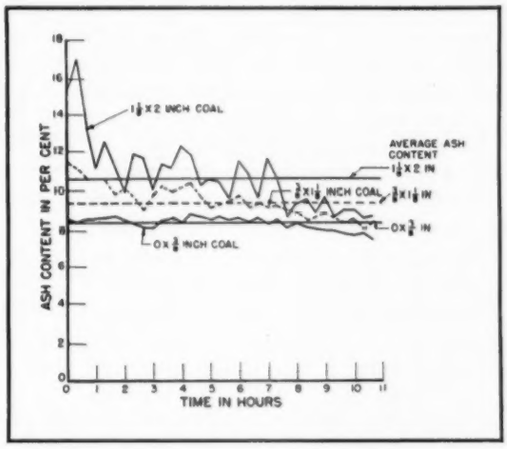


Fig. 4—Variation in ash content of three sizes of coal with time

the individual samples of the larger sizes, however, deviated to a considerable extent from the average and showed a marked decrease for both of the larger sizes as the test progressed. The deviations and downward trend were greater for the 1 1/8 × 2-in. coal.

Both Figs. 3 and 4 indicate the probability of serious error in determining the average size analysis or average ash analysis of a shipment of coal by sampling for one or two hours at the stoker hopper.

Segregation of Coal Because of Density Differences

That the ash content of various sizes of a given coal will vary depending upon the friability of a coal, the distribution of the ash, and the method of mining, cleaning and crushing of the coal is generally understood. Methods of sampling coal have been developed to correct for the natural variation in increments of a total sample. Morrow and Proctor[4] have recently presented a comprehensive discussion of the effect of various factors. Variations in the ash content of coal from various positions in a lot of coal may, however, also exist because of density segregation.

An experiment by Holmes[3,1] in which a mixture of coal and fluorspar of 3 × 6 mesh was allowed to fall into a conical pile, illustrated density segregation in its simplest form. The dense fluorspar particles tended to segregate

[4] "Variables in Coal Sampling," by J. B. Morrow and C. P. Proctor, A.I.M.E. Technical Publication No. 645-F, 67, p. 7, 1935.

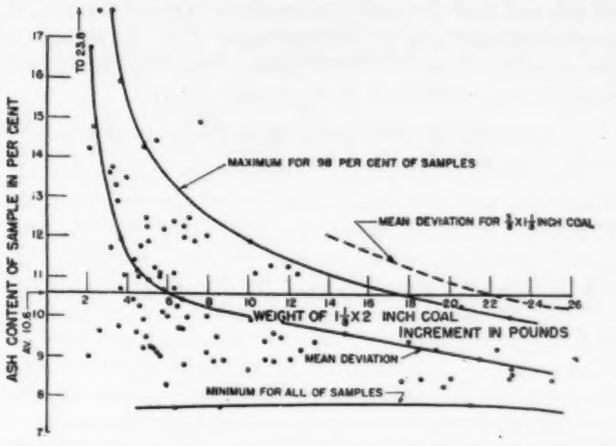

ASH CONTENT OF SAMPLE IN PER CENT
TO 23.6
AV 10.6
MAXIMUM FOR 98 PER CENT OF SAMPLES
MEAN DEVIATION FOR ¾X1½ INCH COAL
WEIGHT OF 1½X2 INCH COAL INCREMENT IN POUNDS
MEAN DEVIATION
MINIMUM FOR ALL OF SAMPLES

Fig. 5—Variation in ash content with weight of increment of 1 1/8 × 2-in. coal

directly below the line of fall. The same effect occurs with coal containing particles having higher than average density because of higher ash content.

As previously discussed, in the early part of the test the coal was probably flowing out of the center of a conical pile and contained principally small coal, the coarser pieces having rolled to the sides. The large pieces that were included in this fine material were those trapped by chance plus those which, because of their greater density, sank into the coal as they hit rather than rolling and sliding off to the edge of the pile. These denser pieces had a greater density because of higher ash content.

After the column of coal directly above the tap hole had been withdrawn, coal from the top of the pile followed it until coarser coal from an appreciable radius from the center of the pile moved down and out of the bunker. Because of density segregation, the large particles in the center of the pile had a higher ash content and the remaining coarse coal had a lower ash content than the average.

Fig. 5 shows the relation between the ash content and the weight of each increment of the 1 1/8 × 2-in. coal. The distribution of the points and the position of the mean deviation curve show that the small increments of coarse coal, which were obtained early in the period of sampling, contained greater than the average amount

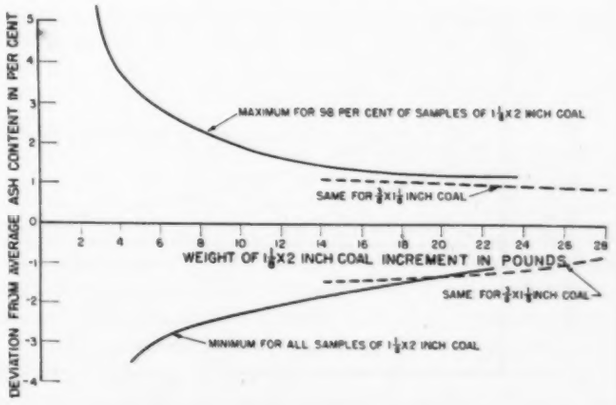

DEVIATION FROM AVERAGE ASH CONTENT IN PER CENT
MAXIMUM FOR 98 PER CENT OF SAMPLES OF 1½X2 INCH COAL
SAME FOR ¾X1½ INCH COAL
WEIGHT OF 1½X2 INCH COAL INCREMENT IN POUNDS
SAME FOR ¾X1½ INCH COAL
MINIMUM FOR ALL SAMPLES OF 1½X2 INCH COAL

Fig. 6—Deviations in the ash content with weight of increment of 1 1/8 × 2-in. coal; corrected for trend due to density segregation

of ash and that the larger increments, later in the period, contained less than the average ash. This is evidence of the segregation of the larger pieces of high-ash coal in the smaller coal because of their greater density.

Variation in Ash Content with Size of Increment

The decreasing spread between the curves for the maximum and minimum deviation as the weight of the increment increased shows that the variability of increments decreased with increase in their weight. The relation is somewhat obscured by the downward trend in the curves because of segregation due to density. Fig. 6 was prepared from Fig. 5 to present this relation more clearly. The ordinates for the maximum and minimum curves were obtained by measurement of the distance of each curve from the mean deviation curve of Fig. 5; in effect, the mean deviation curve was straightened out and made the zero ordinate in Fig. 6.

The latter shows how the deviation of the ash content from the average decreased with increase in the weight of the increment. The relation shown applies only to the particular set of conditions, but it is obvious that in the sampling of coal, which is a heterogeneous material, the effect upon the ash content of an individual sample of the chance inclusion or exclusion of a single piece of stone or slate will be great if the weight of the sample becomes too small.

Fig. 7 shows similar data for the $^3/_8 \times 1^1/_8$-in. coal. The trend of the deviations is similar, but the deviations are not so great because of the smaller size of the pieces and because the weight of the smallest increment was larger than with the larger coal.

Variation in Total Ash Fired

Fig. 8 is a graphical presentation of the variation of the total ash in each size fraction and in the total 0×2-in. coal over the sampling period. The amount of ash is derived from the percentage of ash and the weight of each fraction. Although the amount of ash in each size fraction varied considerably with time, the total ash fired did not vary greatly with this coal. This fact presents another reason why the variation in size did not produce evidence of changes in the fire throughout the time of sampling. Given a different relation of ash content to coal size, these results would have been different.

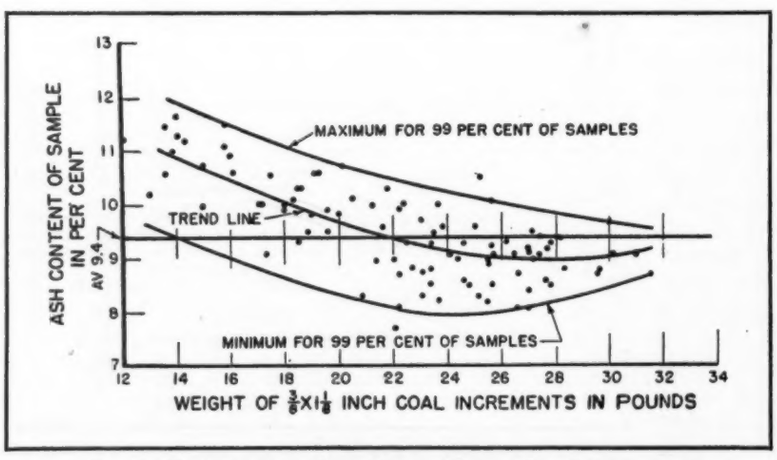

ASH CONTENT OF SAMPLE IN PER CENT
AV 9.4
MAXIMUM FOR 99 PER CENT OF SAMPLES
TREND LINE
MINIMUM FOR 99 PER CENT OF SAMPLES
WEIGHT OF 3/8X1 1/8 INCH COAL INCREMENTS IN POUNDS

Fig. 7—Variation in ash content with weight of increment of $^3/_8 \times 1^1/_8$-in. coal

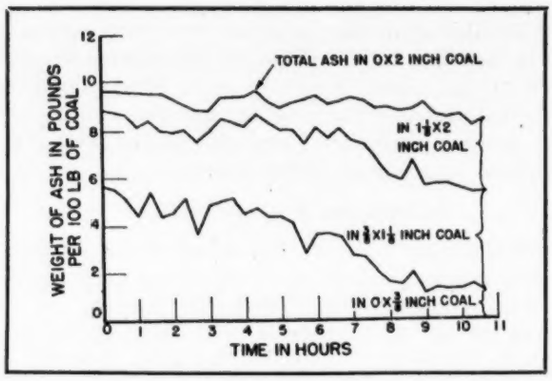

WEIGHT OF ASH IN POUNDS PER 100 LB OF COAL
TOTAL ASH IN 0X2 INCH COAL
IN 1 1/8X2 INCH COAL
IN 3/8X1 1/8 INCH COAL
IN 0X3/8 INCH COAL
TIME IN HOURS

Fig. 8—Relation of distribution of ash in three sizes of coal to time of test

Conclusions

These experimental data and the growing experience of fuel engineers with the effect of coal segregation upon stoker operation indicate that more consideration should be given to the design of bunkers and bunker-loading equipment to reduce or eliminate the variation in coal size and accompanying ash segregation. The following conclusions may be drawn from the experiments.

1. The coal size segregation in the typical parabolic bunker as used in a typical steam plant will cause a wide variation over a period of hours in the size distribution of the coal drawn from the bottom of the bunker.

2. Depending upon the ash distribution in the coal as a function of particle size, the ash content of each cubic foot of coal supplied to the stoker may vary over a narrow or wide range due to bunker segregation.

3. If coal is used which has a wide variation in particle density, an appreciable segregation due to density may be noted; the pieces of high-ash content will tend to go with the small particles.

4. In conducting a coal segregation test of this kind, a large enough number of samples must be taken to permit studies of the trends in order that the variation in ash contents and screen analyses will not obscure the true effects.

5. The data show that even if the producer had carefully loaded the coal into the car to eliminate segregation, the segregation in the bunker would have nullified the care that he had taken. Such segregation occurs on a conical pile whenever the coal is a mixture of different sizes. To insure that all the coal will not be too fine or too coarse for the stoker, each car should be loaded with approximately the normal proportions of each size in the coal as ordered.

6. Although under the conditions of the test reported no serious detrimental effect of the segregation was noted in the stoker operation, it must not be concluded that such effects do not exist. Field experiences indicate that segregation is often detrimental. It would be expected to be more serious with a medium- or weakly-caking coal having a low ash-fusion temperature and a higher ash concentration in the smaller particle sizes, when burned at high rates.

Lubricating Oil for Circulating Systems of Steam Turbines

This discussion of the proper characteristics for steam turbine oils was prepared by request for COMBUSTION by the Technical Staff of the Socony-Vacuum Oil Company, Inc., and covers viscosity requirements, chemical composition, resistance to oxidation and emulsion, and the degree of refining that produces the most suitable oils. The subject is dealt with from a fundamental standpoint.

RELIABILITY of operation and continuity of service are two very important factors in steam turbine practice. Turbines are often expected in industrial plants to run continually for a week or more and for a year in central power stations. If the oil in the system fails, the turbine must be taken out of service and unscheduled shutdowns are costly. Because lubrication has a definite effect upon reliability, this subject is always of interest to turbine operators.

The majority of turbines are lubricated by a pump-pressure-circulation oiling system, although the smaller units are sometimes designed with ring-oiled bearings. In the circulating type of unit the oil performs three different duties. It cools as well as lubricates the main bearings and the governor parts, and makes use of its pressure to actuate the governor mechanism. In geared units, the same oiling system lubricates and cools the gears.

The problem of lubricating the main bearings of a turbine is not difficult in so far as the bearings alone are concerned. Unit pressures are not heavy, and speeds, during actual operation, are high enough to produce perfect oil-wedge action. In fact, the bearing situation is usually so favorable that films of oil completely separate the journals and bearings at all times, except during periods of starting and stopping and idleness. Temperatures, induced through the shaft from the steam end, are kept within reasonable limits by flooding an excess of oil over the bearings and journals, the heat being subsequently removed from the oil by means of coolers. Much the same condition exists in the governor mechanism, so that the problem is not difficult from a strictly lubricating standpoint, nor are any serious difficulties presented in using the oil as an hydraulic medium for governor action.

The principal problem in turbine lubrication is to circulate the oil for long periods of time without producing dangerous changes in its character. The most objectionable changes are the formation of deposits, sludges or emulsions. Oil refiners, turbine builders, equipment manufacturers and operators are all bending every effort to minimize these objectionable formations in turbine oils. The petroleum industry has already produced lubricating oils which under favorable operating conditions function satisfactorily in turbines without replacement for periods of 10 years or more. Nevertheless, intensive research is still under way to develop improved products.

Viscosity Requirements

In considering the requirements of a turbine oil, the viscosity is a characteristic which must be given careful attention. As viscosity decreases, the ability to maintain a fluid lubricating film also decreases. Therefore, light-bodied oils are not best suited for heavy unit bearing pressures. On the other hand, heavy oils produce a noticeable drag on moving surfaces, necessitating increased power input which is dissipated as increased heat in the bearings. Increased heat causes more rapid oil deterioration. Heavy-bodied oils are, therefore, less suitable for the high speeds. Moreover, the action of gravity, in causing impurities to settle out of oil, is slower for heavy than for light oils.

In deciding upon oil viscosity, it is important to select the lightest body that will maintain a separating fluid film between moving surfaces. Experience has shown that for direct-connected units an oil having a viscosity of 150 sec Saybolt Universal at 100 F is a good choice. At the present time, European practice tends to favor somewhat heavier oils. In geared turbines, the unit pressures on the gear teeth (due to line contact) are considerably higher than the unit bearing pressures, and therefore the oil must be selected to sustain these higher tooth pressures. A Saybolt Universal viscosity of 320 sec at 100 F is considered correct for stationary geared units.

During operation, the turbine shaft is spinning at a speed sufficient to drag the oil films completely across the weight-carrying areas of the bearings. This action lifts the shaft and floats it on a film of oil so that there is no longer any contact between shaft and bearing. With this condition existing, the problem of lubricating turbine bearings becomes a matter of pure hydraulics, and the oiliness characteristics of the oil are of little importance. If this were the only condition to be met, any liquid of suitable viscosity could be made to serve the purpose, but the turbine must be started and stopped, and during these periods the shaft speed is insufficient to form or maintain the film of oil. Under a microscope, even the smoothest of bearing surfaces appears as a rough

series of hills and dales. When two such surfaces rub across each other with no separating oil film, the hills strike and are levelled off, resulting in heat and wear. At full speed the turbine bearing creates a separating film far thicker than the height of the hills, but at low speed the hills clash, and a cushioning medium is needed to absorb the shock and minimize the damage. Metal-to-metal contact does occur during starting and stopping periods and oil is required to prevent damage to the rubbing surfaces.

Oil a Complex Chemical Substance

Petroleum has no specific chemical formula. It is one of the most complex chemical substances known, and consists of a countless number of varieties of molecules, all, however, being composed of hydrogen and carbon. Impurities such as sulphur, oxygen, nitrogen, etc., are also usually present in crude petroleum. The different types of molecules have different characteristics ranging from the unstable unsaturated molecule, which is striving always to complete itself by chemically uniting with something else, to the completely stable molecule which resists change.

In refining turbine oil, the aim is always to remove the groups of molecules that are unstable and to preserve those which are stable, keeping in mind, however, that this process of removal cannot be carried too far without sacrificing lubricity. To cushion the interlocking hills of the slowly moving bearing surfaces, an oil is needed which will cling to the projecting points under tremendous local pressures. A bond, approaching actual chemical union between the metal and the oil, is needed, but such a bond cannot be secured with the completely saturated type of petroleum molecule even though it is quite possible (by intensive refining) to produce oil consisting only of the entirely stable hydrocarbons. Such oils are known as U.S.P. White Oils and Technical White Oils. In order to secure the best bearing protection under conditions approaching metal-to-metal contact, it is desirable to have present some of the molecules which possess a greater ability to bond with the metal as stated above. This is best accomplished by preserving the natural lubricants of the original oil.

Resistance to Change Most Important

After the correct viscosity of the oil is established, and adequate lubricity is provided for conditions approaching metal-to-metal contact, the turbine-oil problem then becomes a question of durability, resistance to change and chemical stability.

In the turbine the oil is repeatedly subjected to pressure, to heat, to spraying from bearings, to mixing with air, and to contamination with water. The better the oil quality, the greater the resistance to these circumstances, but where unstable hydrocarbons are present, they will eventually absorb oxygen from the air. Heat always accelerates any chemical process, and in the turbine, the higher the oil temperature, the faster this oxygen absorption will proceed. Ordinarily, a temperature of 130 F is considered good practice for oil returning from the bearings, although units are in satisfactory operation at 170 F. The higher temperatures, however, definitely complicate the problem of stability. Upon absorbing oxygen, petroleum hydrocarbons become acidic. The organic acid so formed increases the oiliness of the oil, due to an increased absorption on the metal surface of the bearings.

This increased bonding ability is thought to be due to the orientation on the metal of strata of polar molecules. Polar molecules are those which contain atoms or groups of atoms, the valence of which is not completely satisfied, thus providing residual valence which attaches to the metal. Metal soaps may also be formed by reaction of organic acids with the metals used in construction of the turbines. If water is not present, this action is not usually troublesome, although in aggravated cases, the oxidized hydrocarbon can be of such type and such strength as to corrode copper parts of the system. Where water is present, the soap acts as an emulsifier to create emulsions that are hard to remove.

Pure water and pure oil can be violently mixed and, upon ceasing the agitation, the oil and water will separate quickly and completely. The introduction of a certain type of additional impurity will, however, cause the oil and water mixture to remain more or less permanently emulsified. Minute particles of solid matter that will readily absorb either oil or water will act as emulsifiers. Substances that reduce the surface tension of either oil or water will cause persistent emulsions. These emulsions may be of a thin fluid nature or may be of a thick sticky plastic character, but in all cases they are potential causes of oil-pipe plugging. The preventive measures taken against emulsions are (*a*) to use oil with high resistance to oxidation, (*b*) to keep oil temperatures moderate, (*c*) to use oils that separate rapidly from water and (*d*) to keep water out of the oil.

Oxidation Causes Acidity

The organic acids created by the oxidation of the less stable hydrocarbons are of numerous types according to the particular combination of carbon, hydrogen and oxygen that takes place. Some types are more active than others, but all are soluble in oil when first formed.

As the percentage of acidity increases, a point of saturation is finally reached where any additional oxidation causes the precipitation of the oxidized hydrocarbon as a microscopic solid particle. The saturation point of hot oil is higher than that of cold oil, or in other words, cold oil will not hold as much oxidized petroleum sludge in solution as hot oil will. Therefore, in a turbine system the excess oxidized portions are precipitated from the oil at the coolest point of the system.

The first step in the creation of either emulsion or sludge is the formation of the oxyhydrocarbons. The measure of the extent of this reaction, in so far as the formation of acidic materials is concerned, is determined by the amount of alkali that is required to neutralize the acidity. The neutralization number of an oil is expressed in terms of the number of milligrams of potassium hydroxide necessary to neutralize the acid in one gram of oil. The neutralization number alone does not identify the type of acid nor the percentage present. Different organic acids have different neutralization numbers. Therefore, the neutralization number is an uncertain index of the sludging probabilities of an oil. Because of this it has been found necessary to interpret neutralization numbers in the light of actual experience in service with the particular oil under consideration and the particular circumstances of operation. Certain chemical structures of oil molecules may have a high

neutralization number and still not sludge, the acids remaining in solution without causing trouble.

Desirable Degree of Refining

In general, the intensively refined oils will have higher neutralization values in use without precipitating sludge, whereas the mildly refined stocks do not show as high acidity and may form sludge more readily. Refiners of high-grade turbine oils select crudes and methods of refining which will assure the greatest resistance to sludge that is consistent with low acidity. A neutralization number of less than 0.75 holds little probability of sludge. For values of over 0.75 it is necessary to consider the type of oxy-acids before predicting sludge probabilities. The Steam Emulsion Test as applied to used oils is of assistance in determining whether the oxyhydrocarbons present are of a type that will cause sludging associated with emulsion formation. Sludge fouls the oiling system, interferes with proper cooling, restricts oil flow and eventually causes shutdown for cleaning.

The oil industry has concentrated on the elimination of the hydrocarbons that are susceptible to oxidation. Present refining methods make it possible to carry this elimination to such extremes that valuable as well as undesirable materials are eliminated. For instance, the elements that furnish oiliness during periods approaching metal-to-metal contact must not be removed. There are present in the natural oil, types of compounds that act to retard the union of oil and oxygen, thus prohibiting the formation of the petroleum acids. Too drastic a treatment of the oil during refining removes these highly desirable natural inhibitors.

Type of Turbine Oil That Is Most Generally Employed

At the present time the type of turbine oil in use in the greatest percentage of the world's important turbines is an oil that has been refined to remove the maximum percentage of unstable hydrocarbons without dangerously decreasing the portion of less stable elements that act as natural metal bonds and as natural inhibitors. The refiners are looking continually for improvements. Development work is under way along lines of supplying artificial lubricity and artificial inhibitors. Materials have been developed that retard the formation of oxy-hydrocarbons for a certain period of time and appear to hold possibilities for future improvement. Experience, however, has been limited to turbine runs which are short as compared to the many instances of 10 to 15 years of service with conventional oils.

The factors of viscosity, lubricity and stability are vital items in a turbine lubricating oil. The stability item is particularly important and is very closely allied to oil quality. Most of the oil difficulties experienced by operators are influenced by oil stability, and turbine oil manufacturers have attempted to produce lubricants that resist change while in use. Thirty-five years of study of oil in action have produced the present-day quality lubricant. The higher quality oils of today are capable of giving service extending over a period of many years. Even better oils are hoped for, but definite proof of progress must await the time when these newly developed products have established definite superiority in long periods of service.

New Power Plant of Carnegie-Illinois Steel Corp.

Carnegie-Illinois Steel Corporation will soon put into operation a new power station, No. 5, at its South Works in Chicago. This will replace older equipment, and provide for future expansion, as well as centralized power facilities. Surplus blast-furnace gas will be used as primary fuel with natural gas and oil as secondary fuels. Provisions have also been made to use pulverized coal for secondary fuel after the bulk of the surplus blast-furnace gas has been utilized for metallurgical purposes. The layout provides not only for storage, handling and pulverizing facilities, but also for dust collectors to prevent the discharge of fly ash from the stacks.

The building will house three 300,000-lb per hr boilers, one 25,000-kw condensing turbine-generator and three 75,000-cfm condensing turbine-driven blowers operating at 3000 rpm against a maximum discharge pressure of 30-lb per sq in. gage. Space is also provided for an additional boiler and a 50,000-kw turbine-generator. Steam will be supplied to the turbine throttles at 450 lb, 750 F.

The boilers are of the C-E four-drum, bent-tube type, each having 22,000 sq ft heating surface, 6200 sq ft water wall surface and 17,150 cu ft furnace volume. Each is equipped with a 7180 sq ft economizer and a 6450 sq ft superheater. Gases leaving each economizer divide and pass through two 26,200 sq ft regenerative type air heaters, thence are discharged by the induced-draft fans to a 14-ft diameter concrete-lined steel stack. Two induced-draft fans of 192,000 cfm capacity serve each boiler, one being driven by a geared turbine and the other by a two-speed motor. There are also two forced-draft fans of 45,000 cfm each per boiler, one motor-driven and the other turbine-driven. The furnaces are fired tangentially and complete automatic combustion control is provided.

Makeup is expected to run about 20 per cent. This water will be taken from Lake Michigan and treated by a hot-process lime and soda-ash softener. Feedwater will be pumped to the boilers by three 3500-rpm centrifugal pumps, each of 750 gpm capacity when operating against a head of 1427 ft. Two of these are motor-driven and one turbine-driven. The feedwater heating cycle will include a 600,000-lb per hr deaerating heater and two closed heaters using steam extracted from the turbine at 80 and 40 lb abs.

Water for the condensers and boilers will be taken from the lake through an intake provided with traveling screens, each having a capacity of approximately 50,000,000 gallons per day, sufficient to meet the needs of a city of about 1,000,000 population. The water will flow by gravity to the station through a 10 × 10-ft concrete tunnel, 1400 ft long. At the station it will be pumped through the condensers by vertical motor-driven pumps. The condensate will be removed by duplicate motor-driven pumps. Twin steam jet air pumps will handle the non-condensable vapors.

Although most of the steam from the boilers is to be used by these turbines, some will be used in single-stage evaporators which will supply 150 lb steam to the plant for miscellaneous uses.

Electrical control equipment will be located in a separate two-story building.

Fly-Ash Data from the Federal Central Heating Plant

By J. F. BARKLEY,
Supervising Engineer, Fuel Economy Service Section, U. S. Bureau of Mines

The following data, published by permission of the Director of the U. S. Bureau of Mines, are taken from tests when burning $^3/_4$-in. slack coal on underfeed multiple-retort stokers. Variation of the fly ash discharge with load is shown as well as the composition of this ash and the relative amounts caught by the cinder trap and the electrostatic precipitator, which are placed in series.

IN the Federal Central Heating Plant at Washington, D. C., there are installed in series, beyond the underfeed stoker-fired boilers, both conventional-type cinder traps and Cottrell precipitators.[1] Table I shows the results of fly-ash tests when using a $^3/_4$-in. slack coal of the following "as-fired" average analysis:

Moisture	3.3
Volatile	24.3
Fixed Carbon	62.2
Ash	10.2
S.	1.3
Btu	13460
Ash Fusion	2600 F

Increasing the fuel rate per square foot of grate area about three-fourths or from 23.0 to 40.5 lb raised the amount of fly ash, expressed as a percentage of the weight of the total coal fired, from 0.73 to 2.80, or about 3.8 times. The actual weight of fly ash leaving the boiler per hour increased from 82.4 to 556.9 lb, or about 6.8 times. At the lower ratings the cinder catcher removed about 50 per cent of the total fly ash and at the higher ratings about 35 per cent. It is estimated that not more than 4 to 5 per cent of the total ash got by the precipitator.

Table II gives the average draft conditions, the flue-gas analyses, the proximate and ultimate analyses of the cinders caught by the cinder catcher, and the proximate and ultimate analyses of the flue dust caught by the precipitator. Table III gives screen analyses of the cinders and flue dust for certain of the tests.

The specific gravity of the flue dust was found to be very much lower on the lower rating tests than on the higher rating, being 0.38 (23.7 lb per cu ft) for tests 1, 2, 3 and 4, and 0.58 (36.2 lb per cu ft) for tests 5 and 6, or about 0.65 as heavy. To determine the cause of this difference in weight per cubic foot, chemical analyses

[1] For cross-section through boiler room, see COMBUSTION, November 1936, p. 29.

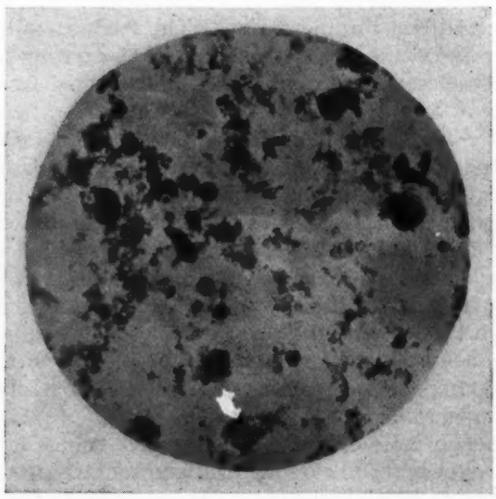


Fig. 1—Photomicrograph showing the lighter flue dust (23.7 lb per cu ft); more light unconsolidated ash, fewer and smaller fused spherical particles than in the heavier flue dust

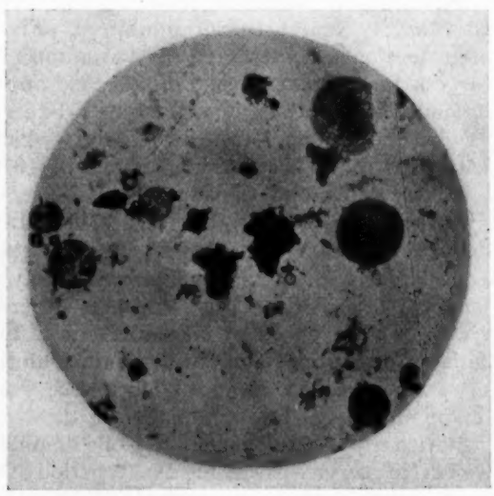


Fig. 2—Photomicrograph showing the heavier flue dust (36.2 lb per cu ft); less light unconsolidated ash, more and larger fused spherical particles than in the lighter flue dust

TABLE I—TEST DATA ON FLY-ASH EMISSION

Test No.	1	2	3	4	Ave.	5	6	Ave.
Coal burned per sq ft of grate per hr, lb	23.0	23.0	22.9	23.2	23.0	40.4	40.6	40.5
Total lb of coal burned per hr	11268	11250	11217	11376	11280	19812	19912	19862
Total lb per hr of fly ash leaving boiler	79.5	62.3	101.4	86.1	82.4	666.4	447.3	556.9
Total lb per hr of fly ash caught by cinder catcher	39.6	30.1	49.4	44.3	40.9	250.0	144.1	197.1
Total lb per hr of fly ash caught by Cottrell precipitator	36.7	29.6	47.8	38.5	38.2	383.1	278.9	331.0
Estimated lb per hr of fly ash going to atmosphere (based on special tests of precipitator)	3.2	2.6	4.2	3.3	3.3	33.3	24.3	28.8
Per cent of total fly ash caught by cinder catcher	49.8	48.3	48.7	51.5	49.6	37.5	32.2	35.4
Per cent of total fly ash caught by Cottrell precipitator	46.2	47.5	47.1	44.7	46.4	57.5	62.4	59.4
Per cent of total fly ash going to atmosphere	4.0	4.2	4.2	3.8	4.0	5.0	5.4	5.2
Per cent of weight of total fly ash to weight of coal burned	0.71	0.55	0.90	0.76	0.73	3.36	2.25	2.80

were made and also photomicrographs. Table IV shows the complete analyses of the two flue dusts and also the ash of the coal used in the tests. The chemical analyses of the flue dusts show little to account for such a great difference in their weights. Besides the carbon content, which is lower in the lighter material, there is little difference in the analyses excepting an appreciably higher percentage of the alkalies (Na_2O, K_2O) and sulphur trioxide (SO_3) in the lighter material which is produced at the lower ratings. This may indicate that the alkalies that give easily formed, melted and volatilized compounds and also the sulphur, quickly get into the flue gases. As the burning rate is increased these increase in total poundage in the flue dust to a considerably less extent per pound of coal than the other fly-ash constituents.

The photomicrograph in Fig. 1 shows the lighter flue dust, and that in Fig. 2 the heavier flue dust. The lighter dust contains more light unconsolidated ash than does the heavier dust. In both cases some of the ash has been fused to a glass which is indicated by the spherical particles resembling marbles; the heavier dust, however, contains more and larger spheres. Under the conditions of the faster burning and higher air pressures occurring at the higher burning rates, more of the larger fused spheres reached the precipitator. This is also indicated in the screen analysis, Table III.

TABLE II—AUXILIARY TEST DATA ON FLY-ASH EMISSION

Test No.		1	2	3	4	Ave.	5	6	Ave.
Air pressure at stoker tuyères—top zone	in. H_2O	1.03	0.98	0.97	1.04	1.01	2.06	2.27	2.17
Air pressure at stoker tuyères—center zone	in. H_2O	1.02	0.98	0.96	1.03	1.00	2.12	2.33	2.23
Air pressure at stoker tuyères—bottom zone	in. H_2O	1.06	1.00	1.02	1.07	1.04	2.20	2.40	2.30
Air pressure at stoker overfeed section	in. H_2O	0.69	0.61	0.77	0.83	0.73	2.11	2.33	2.22
Air pressure at clinker grinder pit	in. H_2O	0.50	0.39	0.44	0.40	0.43	1.76	2.01	1.89
Draft in furnace	in. H_2O	−0.03	−0.03	−0.03	−0.01	−0.03	−0.38	−0.36	−0.37
Draft at boiler outlet	in. H_2O	−0.22	−0.22	−0.24	−0.24	−0.23	−1.21	−1.34	−1.28
Draft in uptake at fan	in. H_2O	−0.37	−0.36	−0.36	−0.33	−0.36	−2.80	−4.33	−3.57
Gas analysis, boiler outlet									
CO_2	%	14.49	14.47	14.43	14.36	14.44	15.73	15.17	15.45
O_2	%	4.71	4.80	4.88	4.80	4.80	3.13	3.91	3.52
CO	%	0.01	0.00	0.00	0.00	0.00	0.03	0.01	0.02
N_2 (by difference)	%	80.79	80.73	80.69	80.84	80.76	81.11	80.91	81.01
Dry gas per lb fuel (as fired), boiler outlet	lb	13.00	13.45	13.33	12.92	13.18	12.01	12.37	12.19
Cinders proximate analysis (dry)									
Volatile matter	%	3.0	1.1	2.2	3.6	2.5	1.8	3.3	2.6
Fixed carbon	%	33.1	25.9	26.8	31.2	29.3	46.8	52.4	49.6
Ash	%	63.9	73.0	71.0	65.2	68.2	51.4	44.3	47.8
Heating value per lb	Btu	5120	3720	4020	5010	4470	6740	8050	7400
Sulphur	%	0.4	0.3	0.3	0.4	0.4	0.5	0.6	0.6
Cinders ultimate analysis (dry)									
Carbon	%	34.5	26.3	27.7	32.9	30.3	46.9	53.5	50.2
Hydrogen	%	0.5	0.1	0.4	0.7	0.4	0.3	0.7	0.5
Oxygen	%	0.4	0.1	0.4	0.5	0.4	0.5	0.4	0.4
Nitrogen	%	0.3	0.2	0.2	0.3	0.3	0.4	0.5	0.5
Sulphur	%	0.4	0.3	0.3	0.4	0.4	0.5	0.6	0.6
Ash	%	63.9	73.0	71.0	65.2	68.2	51.4	44.3	47.8
Flue dust proximate analysis (dry)									
Volatile matter	%	8.7	8.7	8.5	8.5	8.6	3.3	3.2	3.3
Fixed carbon	%	11.4	11.5	12.5	11.2	11.7	22.8	28.3	25.5
Ash	%	79.9	79.8	79.0	80.3	79.7	73.9	68.5	71.2
Heating value per lb	Btu	1750	1660	1900	1640	1740	3230	4120	3680
Sulphur	%	2.3	2.4	2.3	2.3	2.3	0.9	0.8	0.9
Flue dust ultimate analysis (dry)									
Carbon	%	13.4	13.4	14.1	12.6	13.4	23.3	29.7	26.5
Hydrogen	%	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2
Oxygen	%	4.1	4.1	4.3	4.5	4.3	1.6	0.7	1.1
Nitrogen	%	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Sulphur	%	2.3	2.4	2.3	2.3	2.3	0.9	0.8	0.9
Ash	%	79.9	79.8	79.0	80.3	79.7	73.9	68.5	71.2

The flue dust for the average of tests 1, 3 and 4, screens about the same as test 5 up to the 200-mesh screen. The amount of flue dust passing through the 200-mesh screen, however, for the average of the lower rating tests was appreciably higher than for the higher rating test 5, being 75.5 per cent and 64.4 per cent, respectively.

TABLE III—SCREEN TESTS OF FLY ASH

Test No.		1	3	4	Ave.	5
Cinders						
	Through 20 mesh	97.3	98.4	98.4	98.0	86.1
	Through 48 mesh	70.7	76.1	72.5	73.1	45.4
	Through 100 mesh	34.8	41.2	34.2	36.7	17.2
	Through 200 mesh	9.9	13.2	9.5	10.9	4.3
	On 200 mesh	90.1	86.8	90.5	89.1	95.7
Flue Dust						
	Through 20 mesh	99.9	99.9	100	99.9	99.9
	Through 48 mesh	97.0	99.3	96.7	97.7	97.8
	Through 100 mesh	89.1	96.0	87.6	90.9	89.7
	Through 200 mesh	73.1	83.4	70.0	75.5	64.4
	On 200 mesh	26.9	16.6	30.0	24.5	35.6

TABLE IV—COMPLETE ANALYSES OF FLUE DUST AND COAL ASH

	Lighter flue dust, tests 1, 2, 3 and 4	Heavier flue dust, tests 5 and 6	Ash of coal
Bulk specific gravity	0.38	0.58	
Carbon, C	13.4	26.5	
Hydrogen, H	0.2	0.2	
Nitrogen, N	0.1	0.2	
Silica, SiO_2	42.4	36.1	52.7
Aluminum Oxide, Al_2O_3	20.8	20.6	28.2
Ferric Oxide, Fe_2O_3	8.3	9.0	14.0
Calcium Oxide, CaO	1.7	1.5	1.1
Magnesium Oxide, MgO	0.4	0.6	1.0
Sodium Oxide, Na_2O	0.9	0.6	0.3
Potassium Oxide, K_2O	4.0	1.9	2.5
Sulphur Trioxide, SO_3	6.2	1.8	0.2
Sulphide Sulphur	0.0	0.0	
Free Sulphur	0.0	0.2*	
Carbon Dioxide, CO_2	Trace	Trace	
Chlorine, Cl	"	"	

* Doubtful.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request.

Boiler Water Conditioning

"The Inside Story of Boiler Water Conditioning" is the title of an informative 16-page bulletin prepared by the Elgin Softener Corporation, Elgin, Ill. In discussing variations in water and in operating conditions tables are given showing the hardness and impurities in water from typical districts and how the impurities accumulate inside a boiler as the evaporation increases. Dissolved impurities in boiler feedwater are discussed and descriptions are given of the Elgin Sludge Deconcentrator, the Deconcentrator Chemical Treatment System, the Elgin Zeolite-Deconcentrator System and the continuous Blowdown System. Use of the deconcentrator with a lime-soda softener and with evaporators is also discussed.

Control Valves

Hancock Flo Control Valves are described and priced in a new illustrated bulletin issued by the Hancock Valve Division of Manning, Maxwell & Moore of Bridgeport, Conn. These valves are said to be designed so that the fluid flow will be proportional to the angular adjustment of the handwheel, which adjustment may be accurately gaged by a graduated scale and dial affixed to the stem. The construction of the valves is described and illustrated and their uses in various industries are enumerated. Tables give the dimensions and capacities of the various styles and sizes.

Couplings

The Bartlett Hayward Division of Koppers Company has issued a 40-page catalog devoted to Fast's Self-Aligning Couplings. The principles underlying this new design are discussed at length; the coupling is fully described and illustrated; and specifications of the several types are given. Its applications are also discussed.

High-Temperature Steels

Designers of high-temperature installations who use seamless tubing will be interested in the new "Digest of Steels for High-Temperature Service" just published by the Timken Steel and Tube Division of The Timken Roller Bearing Company, Canton, Ohio.

Presented in a 27-page, $8\frac{1}{2} \times 11$-in. booklet, in addition to the analyses and a short general discussion of the recommended applications of each steel, are data on creep strength, corrosion resistance, oxidation resistance, short-time high-temperature properties, coefficients of linear expansion at various temperatures, charpy impact values at elevated temperatures, results of heat embrittlement tests, temperature stress embrittlement data, data on the stability of tensile properties and information on the structural stability of the steels. These data are given for all steels normally used in the high-temperature field, covering killed carbon steel, carbon-molybdenum steel, Silmo, DM, 2 per cent Cr-Mo, Sicromo $2\frac{1}{2}$, 4 to 6 per cent Cr-Mo, Sicromo 5 and 18-8 stainless steel.

This company has also just issued a second pamphlet entitled, "Guide for Users of High-Temperature Steels," which presents technical data relating to the various properties of Timken seamless tubes. In addition to listing all the properties of twelve steels commonly used for high-temperature service in the oil refining, power and allied industries in the form of tubes, this bulletin presents graphically the salient factors affecting the selection of steels for use at elevated temperatures; corrosion, oxidation, strength and stability. A chart is included showing the effect of heating nine different steels in air for 1000 hr at 1000 F, 1250 F and 1500 F, together with the rate of creep for the same steels at 1000 F, 1100 F and 1200 F.

Sodium Aluminate Treatment

Three interesting and informative bulletins have just been issued by National Aluminate Corporation, Chicago. In each, the research and laboratory facilities in that company's unique new windowless building are fully illustrated, including miniature electric and gas-fired boilers for carrying on scale studies at pressures up to 1200 lb and high ratings. One bulletin deals with the Nalco System as applied to water-softening plants; the second with this system as applied to internal treatment; and the third describes the Nalco A. B. System. Numerous photomicrographs are included to show the effects of coagulation with sodium aluminate.

Stellite

Hard-facing with stellite is covered in a 104-page catalog issued by the Haynes Stellite Company, Kokomo, Ind. Applications in various fields are discussed and illustrated, but of particular interest to power men are the sections dealing with steam valves, nozzles, tube cleaners, pulverizer hammers, drag-line conveyors, fan blades, coal crushers, feeders, and similar equipment that is subject to abrasion or cutting.

Temperature Instruments

A new 32-page catalog entitled "Micromax Temperature Instruments for the Steam Plant" has just been published by Leeds & Northrup Company, Philadelphia. This describes three methods of measurement, namely, the thermocouple pyrometer, used for temperatures up to 800 F; the resistance thermometer for low temperatures; and the optical pyrometer for measuring temperatures within the furnace. By means of a line diagram and also a reproduction of a wash drawing of a typical steam plant the numerous points are indicated at which temperatures should be taken in order to maintain operating economies. Micromax indicators, recorders, controllers and accessories, as designed for steam-plant use, are covered in detail.

The Story of Heat

"Heat," a 48-page book described as telling "the dramatic story of man's age-old struggle to control Nature's most powerful force," is a recent publication of Johns-Manville, New York.

Designed to be helpful and informative to the engineer, yet written in the language of the layman, "Heat" provides in concise, usable form, a wealth of information on this important subject. It is divided into five chapters for easy reference. The first deals with the history of heat—early theories and discoveries concerning its nature, and the work done by those men who made possible today's highly complex industrial civilization. The story of what science is accomplishing in the field of heat conservation, and in the development of materials specifically designed for insulation and reduction of heat loss, is contained in the third chapter.

The fourth and fifth chapters are perhaps of most value to engineers and those interested in the subject of heat conservation. These describe modern materials available for conserving heat, and the specific uses of these materials. How the economical thickness of an insulation is figured, and the reasons why certain insulations are better for one purpose than another, are discussed in detail.

Welded Piping

A 200-page handbook on the design of welded piping, by the oxy-acetylene process, has been issued by the Linde Air Products Company, New York. This supercedes "Design Standards for Oxwelded Steel and Wrought Iron Piping," first published in 1929. The contents include: (1) The engineering aspects of welded piping; (2) Joint design for steel and wrought-iron piping; (3) Cast-iron, galvanized iron, stainless steel and nonferrous piping; (4) Piping layouts; (5) Specifications for welded piping; (6) American tentative standards for wrought-iron and wrought-steel pipe; (7) Data on welding fittings; and (8) Various tables of piping, flange and fitting dimensions, as well as on the linear expansion of pipe. Other features of assistance to designers and draftsmen include standard joint designs, typical headers, expansion bends and riser connections, anchors and supports, and fabrication data. The book is amply illustrated with diagrams, cross-sections and layouts.

Carbon-Molybdenum Steel Pipe for Service at 750 to 1000 F

Tentative specifications for seamless alloy-steel pipe for service at 750 to 1000 F have recently been issued by the American Society for Testing Materials to replace the former "Standard Specifications for Seamless Alloy-Steel Pipe for Temperatures of 750 to 1100 F." The following is a digest of some of the high spots of the new specifications, omitting details as to methods of analysis, testing, inspection, etc., all of which are contained in the text designated as A.S.T.M. A206-37T. This also contains supplementary requirements of an optional nature for central station service covering check analysis, transverse tension tests, flattening tests, finish, metal structure, etching and rejection.

PIPE ordered under these specifications shall be suitable for bending, flanging (vanstoning) and similar forming operations, as well as for fusion welding.

The steel is to be made by either or both the open-hearth or electric-furnace processes, and, unless otherwise specified, all pipe 2 in. nominal diameter and over shall be furnished hot-finished, followed by heat treatment. Also, unless otherwise specified, pipe of this size may be furnished either hot-finished or cold-drawn with, where necessary, a suitable manufacturer's finishing treatment.

Heat Treatment

As to the heat treatment, the finished pipe shall be furnished in the normalized and drawn condition, unless otherwise specified. Normalizing for this purpose is defined as "reheating the finished pipe to 1650 F and cooling in still air to 800 F or below"; and drawing as "reheating the normalized pipe to 1200 F and allowing to cool slowly in still air."

Chemical Composition

The chemical composition specified is as follows:

Grade	Carbon-Molybdenum
Carbon, per cent	0.10 to 0.20
Manganese, per cent	0.30 to 0.60
Phosphorus, max., per cent	0.04
Sulphur, max., per cent	0.05
Silicon, per cent	0.10 to 0.50
Molybdenum, per cent	0.45 to 0.65

Tensile Strength

The material is to conform to the following minimum requirements as to tensile properties at room temperature. (For transverse tension tests the material shall conform to these minimum requirements except that the elongation in 2 in. shall be 25 per cent.)

Tensile strength, min., lb per sq in.	55,000
Yield point, min., lb per sq in.	30,000
Elongation in 2 in., min., per cent	30

Where a definite yield point is not exhibited, the yield strength, corresponding to a limiting permanent set of 0.2 per cent of the gage length of the specimen, is to be reported instead.

Hydrostatic Test

Unless otherwise mutually agreed upon between the manufacturer and the purchaser, each length of pipe shall be tested by the former to a hydrostatic pressure which will produce in the pipe wall a stress of 50 per cent of the minimum specified yield point at room temperature. This pressure is to be determined by the formula: $P = \frac{2St}{D}$, where P is the minimum hydrostatic test pressure in pounds per square inch, S is 0.5 times the minimum specified yield point at room temperature in pounds per square inch, t is the nominal wall thickness in inches, and D is the outside diameter in inches.

The maximum hydrostatic test pressure shall not exceed 2500 lb per sq in. for sizes 3 in. or under in outside diameter, nor 4500 lb per sq in. for sizes over 3 in. to but not including $8^5/_8$ in. outside diameter, and 3000 lb per sq in. for all sizes $8^5/_8$ in. and over outside diameter. This hydrostatic test pressure is to be maintained for not less than 5 sec.

Flattening and Bending

For pipe over 2 in. nominal diameter, a section not less than $2^1/_2$ in. long shall be flattened between parallel plates until the opposite walls meet, and no cracks or breaks shall occur until the distance between the plates is less than one-half the outside diameter, but in no case less than seven times the thickness of the wall. Evidence of laminations or burnt material shall not develop during flattening.

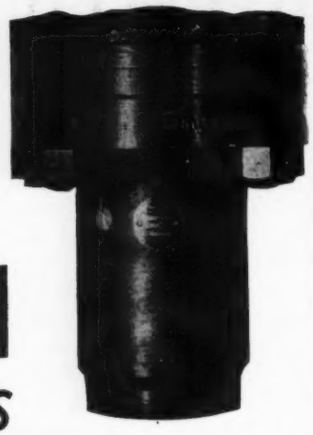
For pipe 2 in. or under a sufficient length shall stand being bent cold through 90 deg around a cylindrical mandrel, the diameter of which is twelve times the nominal diameter of the pipe, without developing cracks. When ordered for close coiling, the pipe shall stand being bent through 180 deg around a cylindrical mandrel the diameter of which is eight times that of the pipe.

Variation in Weight and Dimensions

The weight of any length of pipe in sizes up to and including 12 in. shall not vary more than 3.5 per cent under

FORGED

STEEL STEAM TRAPS FOR HIGH PRESSURES



1. Standard sizes for pressures up to 1500 lbs. with superheat. Higher pressures built on order.
2. Genuine non-collapsible inverted bucket design. Each trap tested against leakage at 3000 lbs. hydrostatic pressure.
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and 6.5 per cent over that specified, while that of 12 in. and over shall not vary more than 5 per cent under or 10 per cent over. Unless otherwise agreed upon, pipe in sizes smaller than 4 in. may be weighed in lots whereas that 4 in. and over shall be weighed separately.

Variation in wall thickness at any point is not to be more than 12.5 per cent under that specified, and variations in outside diameter shall not exceed the following:

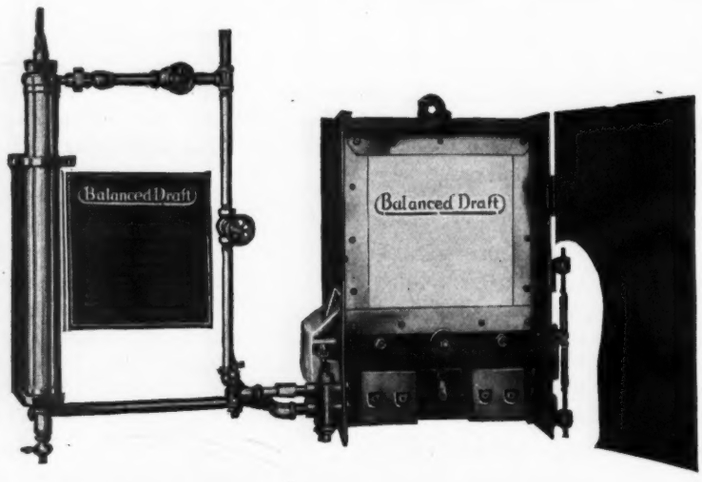
Nominal Diameter	Permissible Variations in Outside Diameter Under	Over
1/8 to 1 1/2 in., inclusive	1/32 in. (0.031 in.)	1/64 in. (0.015 in.)
2 to 4 in., inclusive	1/32 in. (0.031 in.)	1/32 in. (0.031 in.)
5 to 8 in., inclusive	1/32 in. (0.031 in.)	1/64 in. (0.062 in.)
10 to 18 in., inclusive	1/32 in. (0.031 in.)	3/32 in. (0.093 in.)
20 to 24 in., inclusive	1/32 in. (0.031 in.)	1/8 in. (0.125 in.)

Defects

When the depth of a defect encroaches on the minimum wall thickness (87.5 per cent of the nominal thickness) or is in excess of 12.5 per cent of the nominal wall thickness, such defects are to be considered injurious.

Repair of injurious defects shall be permitted subject only to approval by the purchaser and with the understanding that the composition of the welding rod is suitable. Welding of such defects in no case is to be permitted when the depth of defect exceeds one-third of the nominal pipe wall thickness or the length of the repair exceeds 25 per cent of the nominal diameter of the pipe. Defects are to be thoroughly chipped out before welding and then heat-treated in accordance with the instructions mentioned above. Each length of repaired pipe shall be hydrostatically tested as previously mentioned.

Enco Balanced Draft



The Enco Balanced Draft Furnace Pressure Regulator, Type D

Improves Combustion — *Increases the Efficiency of Firemen*
Prevents Positive Pressure — *Improves Heat Transmission*
Prevents Heat Dilution — *Increases Boiler Capacity*
Is Easily Adjusted — *Increases Stack Capacity*
Reduces Furnace Maintenance

80% of the efficiency obtained from Combustion Control is due to proper control of furnace draft.

The Enco Balanced Draft Furnace Pressure Regulator automatically regulates the damper opening and maintains a constant furnace suction at the predetermined point of highest efficiency for each individual fire.

Thousands of Enco installations made during the past 30 years are showing efficient results.

Write for Bulletin 129

THE ENGINEER COMPANY
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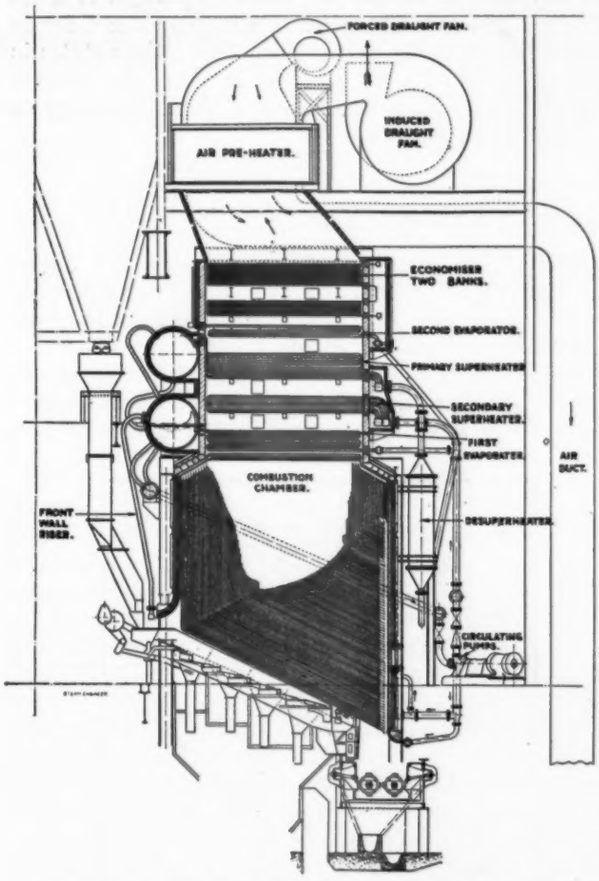
STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Largest La Mont Boiler

The Steam Engineer (London) for November contains a description of the La Mont steam generator now under construction for the Deptford West Power Station of the London Power Company. This is the largest La Mont boiler yet undertaken and is designed for an evaporation of 350,000 lb of steam per hour at 375 lb per sq in.



Section through La Mont boiler at Deptford West Power Station

working pressure and an initial steam temperature of 780 F, although provision is being made for later increasing this to 850 F.

As will be noted from the illustration, here reproduced, the unit is of the single-pass design with the boiler and superheater tubes horizontal, the horizontal position being possible because of the forced circulation. The power saved by the reduced draft loss, due to the single pass, is claimed to more than compensate for that absorbed by the water circulating pumps. The superheater, which consists of primary and secondary sections, is placed in the interdeck position and the second bank of boiler tubes is followed by two economizer banks and the air preheater. All of the boiler tubes are of $1^1/_2$ in. outside diameter and are of cold-drawn mild steel, the lengths being welded together by the oxy-acetylene process. Closely pitched water wall tubes completely line the combustion chamber on all sides and these are backed by refractory material.

Attention is called in the article to a special feature of the La Mont steam generator in that it combines forced circulation with controlled distribution of the water to the boiler tubes by means of orifices located in the tube inlets. These orifices serve the purpose of proportioning the water supply to the tubes in accordance with the heat absorption of the individual tubes.

The unit will be fired by a multiple-retort underfeed stoker designed for a coal burning rate up to 85 lb per sq ft of projected area which corresponds to a heat release in the furnace of 40,000 Btu per cu ft at 350,000 lb per hr evaporation.

Trends in German Power Practice

A most interesting discourse on present trends in German power plant practice is contained in the November issue of *The Power and Works Engineer* (London). Underlying this whole trend is the Four-Year Plan of national self-sufficiency in which technical considerations are giving place to considerations of national economics and policies. Increased attention is being given to the steam power plant because it can be operated entirely on native supplies of hard and brown coal; and the selection of construction materials, together with standardization of steam conditions, capacities and certain component parts of equipment, is being prescribed in line with the Plan.

One of the most significant factors is the reaction in favor of decentralized power production. In this respect, the guiding considerations have been the value of private enterprise and individual responsibility, the desirability of spreading and maintaining employment and the increased security resulting from avoiding dependence on centralized power supply. That is, the older criterion of coal-to-busbar efficiency, favoring extreme centralization, has been abandoned.

Working on these lines, the boiler plant of the industrial establishment assumes greater importance and, according to the National Power Program, equipment must be designed to make the best use of German fuels; also the steam conditions must be selected to permit full utilization of combined power, process and heating requirements. Close attention is being paid to the interconnection of industrial power plants with public utility systems and such interconnection is to be facilitated by the establishment of relatively small central stations at

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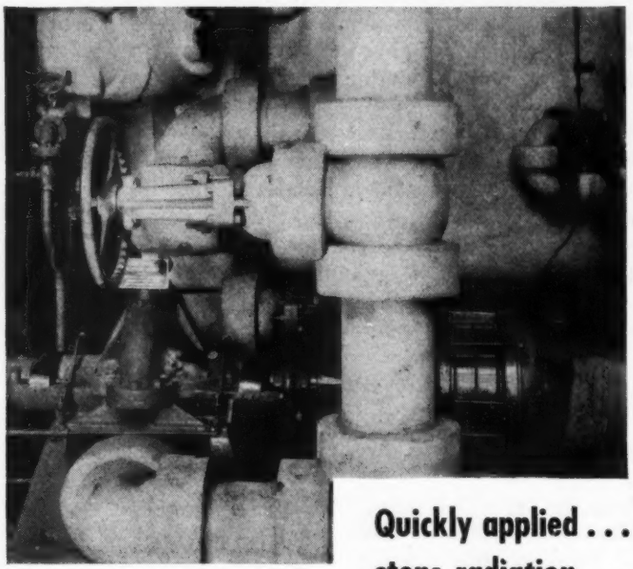

Flanges and fittings in Ontario Paper Company mill, Thorold, Ontario — insulated with Eagle Super "66". Note natural finish.

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local load centers. Thus the ultimate aim of national electrification is to be approached by small increments of capital expenditure.

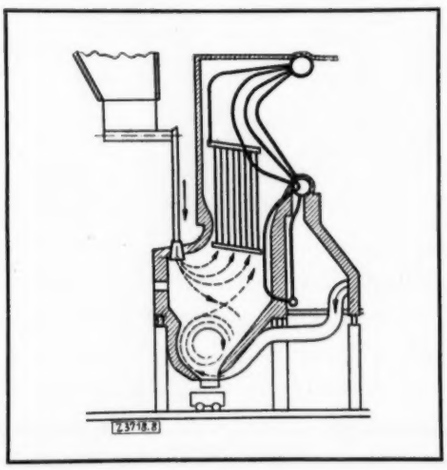
Every encouragement is being offered to industrial concerns to modernize their steam plants in the light of recent statistics which show more than half of the 117,000 boilers in Germany to be over 25 years old. Practice has definitely advanced in the industrial utilization of high steam pressures and temperatures but there is a distinct urge toward increased simplicity and reliability, in view of the economic importance of reducing standby capacity to a minimum.

At one time the demand in Germany for high quality nut coal left a surplus of fines which had to be sold at abnormally low prices, but the subsequent development of furnace equipment to burn these grades brought them into demand, increased the price and left producers with a surplus of the better grades. The outcome has been that the price per million Btu has been brought to much the same level for all grades of coal, and the German State Union of Boiler Supervisory Associations states in its latest report that, "It is advisable not to use furnaces built for special fuels but to insure the adaptability of operation to varying fuels."

Burning Fraised Peat

An article in *Zeitschrift des Vereines deutscher Ingenieure* of October 16, 1937, by Prof. J. W. Arbatsky, describes a new method of burning peat that is said to have proved very successful in Russia.

The peat is mined, after thorough drainage of the moor, by a power-driven fraising machine which consists of a revolving drum with cutters. This machine leaves



The larger particles are kept whirling in the hopper bottom

the peat in a loose crumbled state in which it air dries. To expedite drying it is raked. When thus dried to 30 or 40 per cent moisture it is mechanically stacked.

As a result of considerable experimentation with various means of burning on inclined grates, traveling grates and in suspension, after predrying, a method has been developed that has been most successful. In this method the lighter particles of the prepared peat, still high in moisture, are burned in suspension while passing through the furnace and the heavier particles are kept

in flotation until completely burned, by a whirling air stream introduced tangentially by a blower at the bottom of the furnace.

The sketch illustrates how this is accomplished. The shredded peat is fed in at the top of the furnace and the path of the lighter particles is represented by the upper arrows while the whirling path of the heavier particles is shown by the lower arrows. These heavier particles continue their whirling path in the hopper bottom until dried sufficiently to partially burn after which they become light enough to be carried by the air to the upper part of the furnace where burning is completed.

Large Installation of Benson Boilers

Zeitschrift des Vereines deutscher Ingenieure of September 18 contains a description of the high-pressure extension to the Scholven power plant of the Bergwerksgesellschaft, Hibernia A. G., which serves a group of chemical industries and a nearby colliery. This extension at present consists of three Benson boilers each of 220,000 lb per hr capacity and two similar additional units are on order. The installation is therefore the largest aggregation of Benson boilers in Germany.

These boilers generate steam at 1775 lb pressure and 986 F total steam temperature. The reason for this extremely high temperature is that part of the steam is passed through exhaust-steam reheaters, in which it is reduced 144 deg, on its way to two Ljungstrom turbines of 21,000 kw and 14,500 kw capacity, respectively. The exhaust from these high-pressure turbines, at 185 lb pressure and 428 F, is brought back and raised in temperature to 500 F in passing through the steam reheaters and then goes to the colliery.

The remainder of the steam from the Benson boilers passes through reducing valves and joins the steam from six old boilers supplying steam at 412 lb, 800 F, to two 25,000-kw turbines. Another group of older boilers supplies steam at 185 lb to three smaller turbines and certain auxiliary equipment. This line is also tied in with the exhaust from the high-pressure turbines.

With the first two units a considerable number of tube failures occurred and some defective economizer welds were encountered; also some initial errors in assumptions regarding the distribution of heat absorption had to be rectified. These caused some interruptions to service as a result of which the availabilities of these boilers were reduced to 75 and 77 per cent. With the experience thus gained and the correction of defective materials, the availability in the case of the third unit was raised to 92 per cent. The boilers have been operated for periods of eleven weeks without washing out and salt deposits in the turbines have not been serious.

An Early Forced-Circulation Boiler

Despite the number of forced-circulation boiler types that have appeared in recent years, chiefly abroad, the principle and certain details are quite old, as is disclosed by an article in the November issue of *Engineering and Boiler House Review* (London). This described a water-tube boiler designed and built by Martin Benson of Cincinnati, Ohio, in 1856 (not to be confused with the pres-

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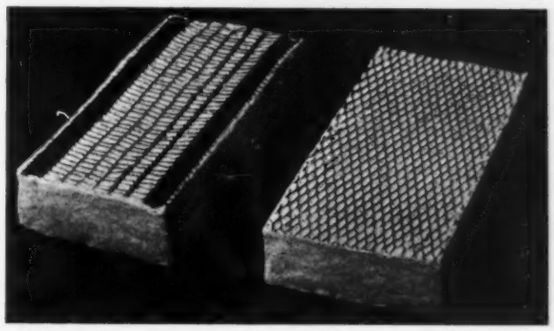

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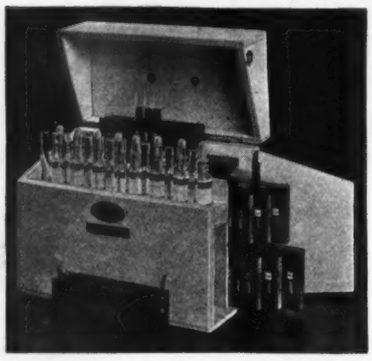

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A 65-page handbook containing a simple explanation of pH control, its practical application to numerous problems, descriptions of our equipment for colorimetric pH, chlorine and phosphate control, also the ***Coleman Glass Electrode,*** sent free on request.

W. A. TAYLOR & CO., INC.
872 Linden Ave. Baltimore, Md.

(*Continued from page 39*)

ent Benson boiler developed by Mark Benson many years later) in which the circulating pump drew water from the steam drum and discharged it into a distributing header to which were connected the lower ends of the steam coils composing the heating surface of the boiler.

Benson reasoned that unless special precautions were taken, it would be difficult to maintain proper water distribution to the coils, as the flow resistance in the individual coils would not be identical, because of inequalities of steam production in these coils under the influences of irregularities in the heat supplied to them. He therefore decided to place a flow-restricting and adjusting nozzle of appropriate aperture, setting up 2 to 3 lb pressure drop, in each of the coils at the point where they were connected to the distributing header. He also was apparently aware that the water supply to the steaming tubes should be kept in a certain ratio to the amount of steam generated, hence provided a water circulation of six to eight times the amount of steam produced. These same principles are incorporated in one of the present-day types of well-known forced-circulation boilers.

The records show that in 1859 ten stationary and thirty-five fire-engine boilers of this type were built and successful operation was reported, but about that time Benson left the United States and moved to England, hoping to introduce his boiler there, but he apparently encountered resistance and was unsuccessful.

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Coal Prices Announced

The National Bituminous Coal Commission has published minimum prices, f.o.b. mines, effective December 16, for coal produced east of the Mississippi and in Iowa.

The prices established for industrial and railroad fuel purposes are somewhat higher than heretofore, being brought in line with the cost of production as provided in the Coal Act. Prices for domestic sizes, however, are generally lower than average prices for such grades in the past. For coals commonly known as steam grades, such as mine run, nut and slack, the Commission used a level from 5 to 20 cents per ton higher than was proposed by the coal industry through the producer boards. Conversely, however, it lowered the prices on double-screened coal, commonly used by the householder, by amounts ranging from 5 to 15 cents per ton below those proposed for the industry. Prices were established on a basis which will permit adjustment of existing freight differentials limited to an amount not in excess of 35 cents per ton.

The Commission emphasized that the minimum prices and marketing rules announced are subject to such revision as may be necessary after further study and consideration. To this end the Consumers' Counsel convened a consumers' conference for the study of these prices, at Washington, on December 7. Pending possible revisions the Commission provided that contracts and orders may not be made for a period longer than thirty days, except in the case of federal, state and local governments whose laws require longer contracts.

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The moving parts of the De Laval-IMO Pump are three rotors. By removing the outboard end-cover and the pump half of the coupling the rotating parts can at once be removed for examination or replacement.

It is unnecessary to break the suction or discharge pipe connections or to move the electric motor. The alignment of the unit is left undisturbed.

De Laval-IMO Pumps are supplied for handling any fuel, lubricating, or hydraulic oils.

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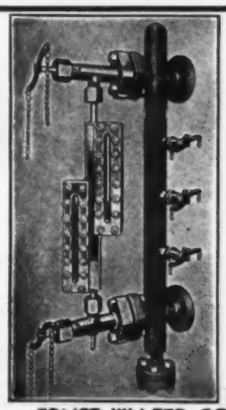

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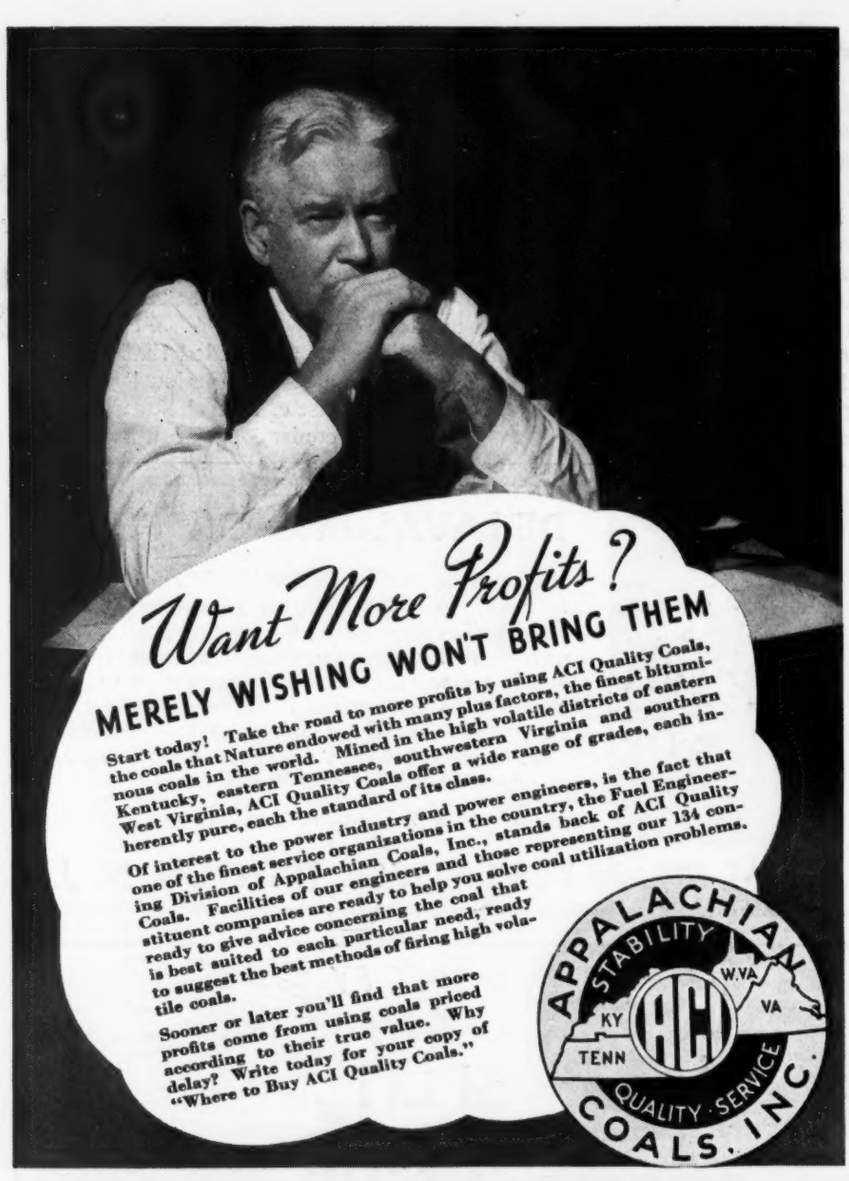
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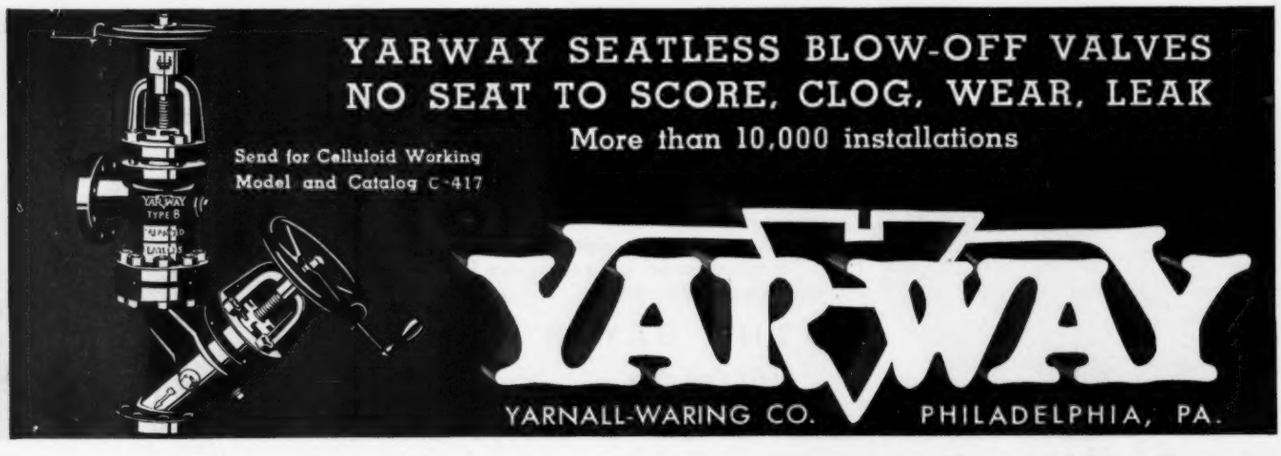
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